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Short-term esthetic considerations of immediate single-tooth implant restorations in the anterior maxilla

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PREFACE

This thesis is based on the following manuscripts:

Chapter 2

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Chapter 4

De Rouck, T., Eghbali, R., Collys, K., De Bruyn, H. & Cosyn, J. (2009) The gingival biotype revisited: transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva. *Journal of Clinical Periodontology* **36,** 428-433.

Chapter 5

Cosyn, J., Sabzevar, M. M., De Wilde, P. & De Rouck, T. (2007) Two-piece implants with turned versus microtextured collars. *Journal of Periodontology* **78,** 1657-1663.

Chapter 6

De Rouck, T., Collys, K. & Cosyn, J. (2008) Immediate single-tooth implants in the anterior maxilla: a 1-year case cohort study on hard and soft tissue response. *Journal of Clinical Periodontology* **35,** 649-657.

Chapter 7

De Rouck T, Collys K, Wyn I, Cosyn J. (2009) Instant provisionalization of immediate single-tooth implants is essential to optimize esthetic treatment outcome. *Clinical Oral Implants Research* **20,** 566-570.

Chapter 8

De Rouck T, Collys K, De Bruyn H, Theuniers, Cosyn J. (2009) Restorative key elements for a predictable aesthetic outcome of immediate single-tooth implants. *Quintessence International* Submitted

LIST OF ABBREVIATIONS

ANOVA	analysis of variance
CL	crown length
CW	crown width
CW/CL	crown width / crown length ratio
DRG	delayed restoration group
dpi	dots per inch
Fig.	figure
GBR	guided bone regeneration
GT	gingival thickness
GW	gingival width
IRG	immediate restoration group
NS	not significant
PD	probing depth
PES	pink aesthetic score
PH	papilla height
RCT	randomized controlled trial
RPD	removable partial denture
Sa	arithmetic average height deviation
SD	standard deviation
WES	white esthetic score

GLOSSARY

(Journal of Prosthetic Dentistry 2005)

Dental Implant

A prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal and/or the periosteal layer and on/or within the bone to provide retention and support for a fixed or removable dental prosthesis.

Alveolar Socket

One of the cavities within the alveolar process of the maxilla or mandibula in which the attachment complex held the root of a tooth after its removal.

Dental Implant Abutment

The portion of a dental implant that serves to support and/or to retain any fixed or removable dental prosthesis.

Alveolar process

The cancellous and compact bony structure surrounding and supporting the teeth.

Gingiva

The fibrous investing tissue, covered by epithelium, which immediately surrounds a tooth and is contiguous with its periodontal membrane and with the mucosal tissues of the mouth.

Graft

A tissue or material used to repair a defect or deficiency.

Guided bone regeneration (GBR)

A surgical procedure that uses barrier membranes to direct growth of new bone at sites having insufficient volume or dimension for function or prosthesis placement. At present, guided bone regeneration is predominantly applied in the oral cavity to support new hard tissue growth on alveolar ridge to allow stable placement of dental implants.

One-stage Surgery

The surgical procedure to install one or more implants into the recipient bone site. The procedure entails only one surgical intervention. After insertion of the implant, the permucosal connection with the oral cavity is immediately assured by mounting the healing abutment onto the implant. The mucosal tissues are sutured around the healing abutments and act as a healing scaffold during a non-submerged healing.

Two-stage Surgery

The surgical procedure to install one or more implants into the recipient bone site. The procedure entails two surgical interventions. The first stage surgery refers to the placement of the implants, followed by suturing the mucosal tissues over the implants. The implants remain submerged underneath the mucosal tissues for a healing period prior to being placed into function. At second stage surgery that portion of the implant that receives the attachment device is re-exposured and mounted with a healing abutment, which secures the permucosal connection with the oral cavity. Hence, mucosal tissues are sutured around the healing abutments to assure soft tissue healing preceding the start of the prosthetic procedure.

Surface Roughness

Dental Implants can also be characterized by their macroscopic and microscopic surface configuration. Macroscopically, we deal with two basic types of implants: screws and cylinders. Microscopically we deal with an assortment of surface treatments and coatings leading to a surface enlargement and an increasing bone-to-implant contact area. All these surface treatments are designed to promote osseointegration. Based on their surface topography, dental implants can be subdivided into 3 categories: minimally rough ($Sa < 1$ µm), moderately rough (1 µm $< Sa < 2$ µm) and very rough ($Sa > 2$µm). Originally implants from the minimal and very rough group were used, but nowadays the majority of the implants used in clinical practice belong to the moderately rough group. A new tendency is to modify the implant surface on a nanolevel.

Immediate implant placement

Implant placement immediately following tooth extraction.

Early implant placement

Installation of the implant earlier then 12 weeks after extraction.

Conventional implant placement

Implant placement later than 12 weeks post-extraction.

Delayed Loading

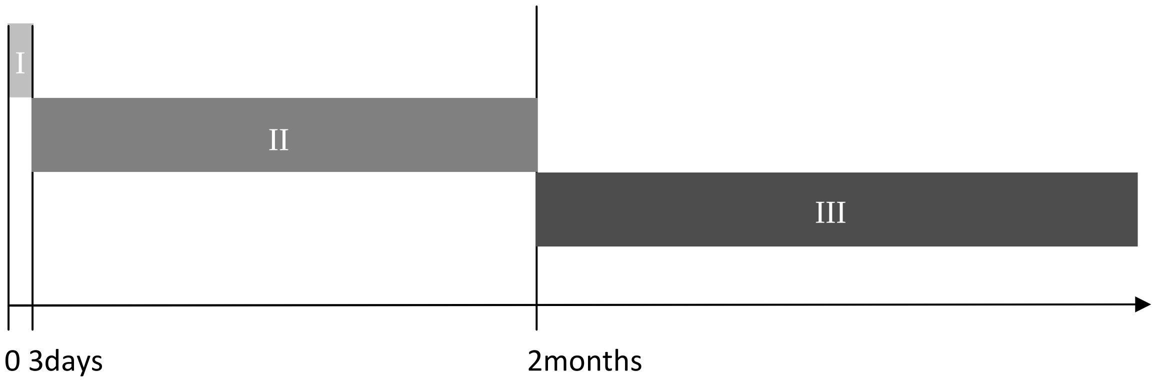
The implants are attached with the prosthesis at least 2 months after implant installation.

Early Loading

The implants are loaded with a time frame between implant insertion and prosthesis connection of less than 2 months after implant installation.

Immediate Loading

This loading protocol is defined as a situation where the implant-supported prosthesis is connected to the implants within 72 hours after insertion.



0	Implant installation
I	Immediate loading
II	Early loading
III	Delayed loading

REFERENCE

Journal of Prosthetic Dentistry (2005) The glossary of prosthodontic terms. *Journal of Prosthetic Dentistry* 94, 10-92.

Chapter 1

General introduction

REPLACEMENT OF A SINGLE ANTERIOR TOOTH

Dental replacements are of all times, and already have a long history. Etruscans and Egyptians (fig.1.1) knew techniques to replace missing teeth. It is striking that most of the recovered restorations were made for the frontal area which indicates that the lack of frontal elements was perceived as very radical for the patient.

Figure 1.1 Acient Egyptian bridge

Nowadays the loss of a single tooth, especially when it occurs in an esthetical compromising area, is still experienced as a traumatic event. The loss of a tooth may alter our confidence and self-esteem and affects us socially and professionally. In such situations clinicians are urged to restore the single missing tooth by an appropriate treatment. Until the mid-20th century, the only available tooth replacements were removable prostheses (acrylic or cast metal denture) and fixed partial dentures (bridge).

The *acrylic removable partial denture* (fig.1.2) is generally made of polymethyl methacrylate. Lately, this kind of restoration is no longer an option for many patients because the bulky removable appliance is unstable, loosely attached and may interfere with speech. Apart from being uncomfortable for the patient, the removable partial denture may also involve other disadvantages (Priest 2006). As a result of an ongoing bone resorption of the edentulous area (Schropp et al. 2003, Araujo & Lindhe 2005) and their purely mucosal support, the prosthesis will lose stability causing functional and esthetical problems. This may further lead to damage to the remaining teeth, loss of occlusal stability and gum stripping (Zlataric et al. 2002). The supporting teeth become more at risk for tooth decay, because food and plaque may easily remain underneath the partial denture (Vermeulen et al. 1996). Usually clasps are used to retain these dentures, which often interfere with function and esthetics. First, they may impede occlusion if interocclusal space is limited. If there is inadequate space between opposing teeth even for thin clasp wires, patients must rely on undercuts in the acrylic resin base or resort to denture adhesives. Second, visible clasps may further interfere with the esthetic expectations of the patient (Priest 2006).

Although benefits are few, they do exist: simplicity of fabrication, cost, and ease of insertion are the most compelling advantages of this restoration. An additional advantage is the ability to modify the acrylic denture to accommodate any changes in the ridge anatomy for patients who may require multiple procedures of extraction, soft- and hard-tissue augmentation, and implant placement. These advantages makes it an appealing interim solution to replace a failing tooth during implant therapy, as adjacent teeth are not involved and it is easily and quickly installed for a favorable cost benefit ratio (Priest 2006, Cho et al. 2007).

Figure 1.2 Acrylic removable partial denture

The *cast metal removable denture* (fig.1.3) offers a better answer. By incorporating dental support occlusal stability is better maintained and gum stripping can be avoided. On the other hand as the denture is supported by the remaining teeth, they will have to sustain extra forces, which can lead in the long term to tooth mobility and gum irritation (Zlataric et al. 2002). The 10-year survival rate of this type of restorations is about 50 % (Vermeulen 1996). This restoration is not only less flexible with regard to modifications but esthetics are also marred by unavoidable anchor arms. Furthermore, an increasing number of patients is reluctant to replace their missing teeth with a removable device.

Figure 1.3 Cast metal removable denture

The only tooth replacement that approaches best the feeling of natural teeth is a *fixed partial denture (bridge) (fig.1.4)*. The neighboring teeth are prepared for the fitting of a fabricated 3-unit bridge that is cemented onto the abutment teeth. Concurrently this is one of the major shortcomings of this alternative as significant tooth reduction of the abutment teeth is necessary to fit the bridge. In some cases, if the latter are severely restored or broken down, abutment teeth will benefit from a fixed partial denture, as they are hereby reinforced. It is a stable solution with good esthetics and function that is usually completed in a short time. However, it might be considered as an iatrogenic mistake to sacrifice sound tooth material of a pristine dentition in order to install a fixed partial denture. Moreover, the reduction of the abutment teeth may result in an increased incidence of endodontic therapy and root decay (Cheung et al. 1990, Goodacre et al. 2003). If this leads to the failure of one part of the bridge, the consequences may be radical and result in the failure of the whole restoration. Another disadvantage is the lack of support for the bone previously surrounding the tooth. This may result in continuous bone resorption in the edentulous area underneath the bridge and eventually lead to an unattractive smile. From a hygienic point of view the bridge restoration is also a less inviting strategy, since it may cause some extra difficulties for the patient to floss under the pontic tooth. In most of the cases the patient has to rely on additional aids. The most obvious advantages of a fixed partial denture may be its predictability and survival: a systematic review indicated a 10-year survival of conventional tooth-supported fixed dental prosthesis of 89 % (Pjetursson et al. 2007).

Figure 1.4 Fixed partial denture (bridge)

The increased awareness of healthy teeth makes it less and less acceptable to grind down sound teeth 360 degrees with the only purpose to replace a single failing tooth. Especially since every prosthetic restoration needs replacement in the future. The *resin-bonded bridge* (fig.1.5) was introduced as an alternative to a traditional fixed partial denture. It offers a more conservative method of tooth replacement because tooth preparations are limited to the approximal and lingual/palatal surfaces of the adjacent abutment teeth. However, these preparations are more technique-sensitive because they must remain in enamel; yet, provide occlusal clearance and adequate room for the restorations. Furthermore, preparation of these lingual/palatal surfaces can be problematic with cast-metal resin-bonded prostheses, since thin or translucent teeth are unable to mask the palatal metal retainers, thus lowering the value of the adjacent teeth, and proximal metal margins may be visible (Priest 2006). Major disadvantages of the resin-bonded bridge are the poor long-term success, as demonstrated by the 5-year survival percentage of 87 % of a systematic review (Pjetursson et al. 2008), and the frequency of debonding. Debonding rates of 25-31% have been reported (Williams et al. 1989, Hussey et al. 1991). Again, with the absence of a natural tooth root, the bone above the crown begins to shrink and, as already described above, the patient may be confronted with some extra complications in hygienic maintenance.

Figure 1.5 Resin bonded bridge

In the eighties it became possible to replace missing teeth by using *implants (fig.1.6),* hereby not compromising the integrity of the sound teeth adjacent to the edentulous area. Teeth are not prepared and thereby not linked as part of the restoration. The missing natural tooth root is replaced with a dental implant that is inserted into the bone. The dental implant integrates, helping to preserve most of the bone previously surrounding the tooth root. Onto this osseointegrated implant an abutment is mounted and the crown is secured to the abutment. Since osseointegration is a relatively slow process, rehabilitation with an implant-supported restoration is a time-demanding procedure. Completing an implant-supported restoration takes longer than to complete a 3-unit bridge, but costs are comparable if hard and/or soft tissue grafting are not required. If bone volume or soft tissues are inadequate, these procedures become necessary making the procedure more demanding. However, achieving the utmost esthetic result with a bridge often also requires supplementary soft/hard tissue grafting at the pontic area. The 10-year survival percentages of the single-tooth implant reached similar results as the tooth-supported fixed partial denture (89 %) (Pjetursson et al. 2007).

Figure 1.6 Implant-supported crown

WHAT IS A DENTAL IMPLANT?

A dental implant is an artificial root that is placed into the jaw to hold a crown, bridge or denture. The most widely accepted and successful is the titanium implant and is based on the discovery by Professor Per-Ingvar Brånemark (1969). This implant consists of a titanium screw, with a turned or micro-roughened surface. Its success is attributed to the potential of titanium to form an anchorage with the surrounding bone. Osteoblasts are stimulated to produce bone on the surface of the implanted titanium. This forms a structural and functional connection between the bone and the implant, and can, from that moment on, be considered as an osseointegrated implant.

Dental implants are an ideal treatment option for people in good general and oral health who have lost a tooth or teeth due to periodontal disease, caries or trauma, or to replace congenitally missing teeth.

History

The earliest known examples of endosseous implants date back to the Mayan civilization, 1,350 years before Per-Ingvar Brånemark started working with titanium. In 1931 archaeologists found a fragment of a mandible of a Mayan woman in her twenties dating from about 600 AD. The sockets of three missing lower incisors contained three tooth shaped pieces of shell. At first scientists believed that these were inserted after death as observed in the ancient Egyptians. Until forty years ago in 1970 several radiographs revealed compact bone formation around two of the shells which indicates that these were inserted during life.

As with many great discoveries the bone integration capacities of titanium were accidentally discovered. Scientists of the Cambridge University constructed a chamber of titanium which was embedded into the soft tissue of rabbit ears to study the blood flow in vivo. Per-Ingvar Brånemark, a Swedish orthopedic surgeon, studied in 1952 bone healing and regeneration using the same ‘rabbit ear chamber’ in the femur of the rabbit. At study termination he attempted to retrieve these expensive bone chambers but failed to remove them. Bone had grown into close contact with the titanium that effectively remained on the metal, which contradicted contemporary scientific theory. Based on this observation Brånemark conducted many further studies on the phenomenon. Animal and human studies all confirmed this exceptional property of titanium.

Originally he intended to centre his studies on knee and hip surgery, but eventually decided that the mouth was more accessible for continued clinical observations and included more subjects since edentulism is widespread in the general population. He termed the intimate contact between bone and titanium as ‘osseointegration’. In 1965 the first titanium dental implant was placed by Brånemark into a human volunteer, Gösta Larrson.

Reports on the concept of osseointegration were first published by Brånemark and colleagues in 1969 (Brånemark et al. 1969). The next decade, Brånemark reported on the use of titanium in dental implantology in many studies. In 1978 he entered into a commercial partnership with the Swedish defense company, Bofors AB, for the development and marketing of dental implants. Bofors (later to become Nobel Industries) founded in 1981 her daughter company Nobelpharma AB (later to be renamed Nobel Biocare) to focus on dental implantology. Presently hundreds of other companies produce dental implants (Wikipedia).

Osseointegration

Osseointegration is a clinical process in which an alloplastic material is rigidly fixed and maintained in bone during functional loading (Albrektsson et al. 1994). Although this definition appropriately describes the clinical observations of an osseointegrated implant, it does not explain the biologic processes of bone formation and maintenance at the implant to bone interface. Insertion of an implant into the bone triggers a cascade of cellular and molecular events, resulting in a primary bone healing and bone deposition around the alloplast. The first evidence of the direct bone-to-implant contact at light microscopical level was given by Schroeder and his colleagues (1976). After achieving a maximum bone deposition, a continuous and dynamic process of bone resorption and bone apposition maintains the implant to bone interface.

Upon implant placement, the gap between the prepared bone cavity and the implant surface fills with blood. Rapidly a blood clot and fibrin matrix will be formed and platelet blood cells will release a multiplicity of growth factors and cytokines to initiate wound healing. As a matter of fact the blood clot serves as a physical barrier to prevent further bleeding, as a reservoir of growth factors and cytokines, and as a matrix for cell migration. Gradually, a granulation tissue is formed. This granulation tissue is rich of new blood vessels to maintain the high cellular activity (Cardaropoli et al. 2003). Osteogenic cells migrate towards the implant surface through the biological matrix of fibrin resulting in bone formation, defined as osteoconduction (Davies & Hosseini 2000). After 3 weeks the formation of woven bone is started and is marked by osteoblasts producing bone proteins. In the second month, woven bone is gradually replaced by lamellar bone (Davies 1998, Berglundh et al. 2003). Lamellar bone has a high strength necessary for a rigid fixation of the implant. By the third to fourth month maximum bone deposition is achieved. From this moment on bone remodeling (bone resorption and deposition) begins and continues throughout life (Stanford & Brand 1999). Total bone connection to the implant rarely occurs. Clinically observed osseointegration corresponds to 60-80 % of bony contact histologically (Albrektsson et al. 1993).

Bone deposition on the implant surface results from two distinct mechanisms: distance osteogenesis and contact osteogenesis. Distance osteogenesis is a reparative reaction of the host. Microdamage of the bone, induced throughout surgical site preparation, stimulates bone deposition at the surfaces of the prepared cavity. Contact osteogenesis occurs at the surface of the implant and relies on bone deposition directly onto the implant surface (Davies 1998). Distance and contact osteogenesis together result in the juxtaposition of bone to the implant surface.

Dental implant versus natural tooth

Ideally, successful implant-supported restorations should imitate the appearance of natural teeth (Belser et al. 2004). Still achieving a restoration that cannot be distinguished from a natural tooth remains a challenge for every clinician. In restorative dentistry, esthetics often depends upon the creation of harmony and symmetry with the crown of the adjacent teeth as well as with the contralateral tooth (Meijer et al. 2005). However, nowadays esthetics are not only dictated by the form and color of the crown, also peri-implant tissues contribute to the esthetic appearance of the restoration (Fürhauser et al. 2005). Peri-implant tissues should be in perfect harmony with the surrounding tissues of the neighboring teeth. In order to create a natural appearance of the restoration, one should be aware of the fundamental differences between the surrounding tissues of an implant and a natural tooth. These basically include histological and physiological differences of the soft and hard tissues at the interface with the tooth root or implant.

Both peri-implant and dentogingival complexes consist of junctional epithelium, connective tissue and bone tissue. The connective tissue of the natural tooth is rich of blood vessels and contains collagen fibers which are mechanically attached in the cementum of the root acting as a physiological barrier against infiltration of oral bacteria. Furthermore, these collagen fibers suspend the root in its socket forming a non-rigid connection between the alveolar bone and the root cementum. This non-rigid connection assures sensibility for tactile stimuli through pressure receptors. In contrast, the peri-implant connection unit of the artificial root (*i.e.* the implant) shows no physical attachment with the connective tissue (Capri 2006). On the microscopic level the connective tissue surrounding the implant resembles closely with an inflammation-free scar tissue formation. It is characterized by absence of blood vessels and abundance of collagen fibers. The dense zone of circular fibers, mostly running parallel to the titanium surface without attaching to it, forms a tight seal between the oral environment and the peri-implant bone (Berglundh et al. 1991, Buser et al. 1992, Moon et al. 1999). In addition, the implant is in direct contact with the alveolar bone forming a rigid connection (similar to the ankyloted tooth) which eliminates any tactile sensibility.

Another essential factor to achieve an esthetical satisfying restoration is a good understanding of the biological width. In 1961 Garguilo (1961) found that the junctional epithelium and the connective tissue of the natural tooth form a physiological stable structure, called the biologic width. This unit is characterized by specific dimensions, mean measurements revealed 0.97 mm of junctional epithelium and 1.07 mm of connective tissue. Since the implant-supported single-tooth restoration became more popular, several researchers gave increasing attention to study the biologic width of the periimplant tissues (Berglundh & Lindhe 1996, Abrahamsson et al. 1997, Hermann et al. 2001). In contrast with the natural tooth, these dimensions are a more complex issue. Biologic width dimensions of implant supported teeth vary depending on implant design (one-piece and two- piece implants) and surgical approach (submerged and non-submerged technique) (Hermann et al. 2001). These dimensions are a key determinant of esthetics, since they are one of the critical factors that define the gingival height.

CHANGES IN IMPLANT TREATMENT PROTOCOL

Before any oral rehabilitation is started, a precise treatment plan should be formulated. This planning should consider all alternative treatment options in order to choose for each particular patient the best possible treatment. If an implant-supported restoration is the treatment of choice, the start of the procedure to restore the missing teeth should be preceded by a meticulous pre-surgical planning. Based on the ideal location of the restoration and the available underlying bone structures visualized on the radiographic images, the best implant position and inclination are chosen. These are of great importance and should be determined before the actual surgical phase is started.

Classical (Brånemark) protocol

The original protocol advocated implant installation in two surgical interventions and was only started after an initial 2 to 3 months of alveolar ridge remodeling following tooth extraction. The complete implant-supported reconstruction process could take from 5 to 9 months and in some cases longer. After appropriate anesthesia of the surgical area, an incision was made and a mucoperiosteal flap was reflected. At edentulous jaw sites, a pilot hole was drilled into the recipient bone, taking care to avoid vital structures. This pilot hole was then expanded by using progressively wider drills. The implant screw could be self-tapping, and was screwed into place at a precise torque hereby avoiding overload of the surrounding bone. Once the dental implant was secured in place, a cover screw was placed and the wound was sutured. It was believed that the implant had to be covered by soft tissue to avoid epithelial down-growth between the bone and the implant and to minimize the risk for premature loading and infection. The operation site was allowed to heal for a few months. From this moment on osseointegration began. The jawbone grows onto and unites with the surface of the dental implant. This is in contrast to implants surrounded by fibrous connective tissue. To avoid fibrous connective tissue formation, an initial uneventful healing period of several months was advocated for decades. Osseointegration in the maxilla needed 6 months and in the mandible 3 months. These guidelines were empirically based on clinical experience rather than on knowledge of biological principles. Many clinicians used these healing times in studies and, as such, 3 months in the mandible and 6 months in the maxilla became established as the conventional healing period.

After the osseointegration period the implant was uncovered in a second surgical procedure and a healing abutment was placed onto the implant. Finally, the peri-implant mucosa was sutured around the abutment assuring the transmucosal connection. The restorative procedure was started after another 6 to 8 weeks healing of the mucosal tissues. Impressions were taken to make a custom abutment and the restorative rehabilitation.

Innovative treatment concepts

The earlier described surgical and restorative protocol implicates a total treatment period of at least 5 to 6 months in the mandible and 8 to 9 months in the maxilla. Moreover, the procedure entails some inconveniences for the patients. That is, avoiding the use of any prosthesis during the first weeks to ensure an unloaded healing condition, followed by the use of a temporary removable denture which compromises patient’s comfort, chewing ability, possibly speech and esthetics. In addition, this approach requires a second surgical intervention to expose the implant after the osseointegration period. These concerns have commonly caused psychological, physiological and sociological challenges for patients who underwent implant treatment over the past 30 years. Hence, for some patients these disadvantages may influence the decision to rehabilitate by means of dental implants.

As a result a shorter treatment concept urged itself and several authors proposed and studied different protocols. In a first step, the original protocol was modified by investigators to include one-stage surgery, which resulted in similar success rates as with the two-stage protocol (Becker et al. 1997, Buser et al. 1997). Furthermore, since bone loss occurs mainly in the first 3 months after extraction of the tooth (Schropp et al. 2003), clinicians were tempted to insert the implants earlier after tooth loss. Some even placed implants immediately after tooth extraction and combined as such post-extraction bone healing with osseointegration (Lazzara 1989, Becker & Becker 1990, Becker et al. 1991, Tolman & Keller 1991, Werbitt & Goldberg 1992, Gelb 1993, Polizzi et al. 2000, Gomez-Roman et al. 2001). Besides immediate implantation, the time gain may as well be optimized by shortening or even eliminating the load-free healing period following implant placement. Initially immediate loading was only adopted if implants were splinted with a fixed cross-arch suprastructure (Salama et al. 1995, Schnitman et al. 1997, Tarnow et al. 1997, Randow et al. 1999, Bergkvist et al. 2005, Degidi et al. 2005, Ibanez et al. 2005, Östman et al. 2005). The promising results of these reports have led to further studies on early and immediate loading of single-tooth implants mainly investigating the effects on implant survival (Randow et al. 1999, Ericsson et al. 2000, Chaushu et al. 2001, Cooper et al. 2001, Andersen et al. 2002). As implant survival and success rates presented similar results compared to the original protocol, esthetics became the main focus of interest. Due to increasing esthetic demands and the ongoing quest to reduce treatment time, some authors combined immediate implantation with immediate provisionalization to replace a failing single maxillary tooth (Chaushu et al. 2001, Lorenzoni et al. 2003, Kan et al. 2003, Ferrara et al. 2006). Indeed, apart from the time gain, hard and soft tissues may be maximally preserved, as this strategy combines extraction healing with implant healing. However, most of these reports focused on implant survival and preservation of hard tissues. Still, achieving a single-tooth implant-supported restoration with a 'natural' soft and hard tissue appearance remains a challenge for every clinician. An important but delicate part in this are the peri-implant tissues. These tissues contribute to the esthetic outcome of the restoration and should be in perfect harmony with the surrounding tissues at the neighboring teeth (Fürhauser et al. 2005). Also from the patient's point of view, the immediate replacement of a failing tooth seems an attractive treatment protocol as this is a one stage procedure eliminating the need for a removable partial denture. Hereby, the patient benefits from immediate esthetics and comfort.

In a recent systematic review, den Hartog and colleagues (2008) identified four different treatment strategies to replace a missing tooth by means of an implant restoration. Implants were either immediately/early placed after tooth extraction or conventionally after an initial healing phase. Both protocols were combined with either immediate/early or conventional restoration. Remarkably, all these different strategies for single-tooth implants revealed comparable implant survival after one year. In table 1 the calculated survival rates from a meta-analysis of den Hartog and colleagues (2008) are presented.

Table 1. Single-tooth implant survival rates after 1 year (den Hartog et al. 2008)

Intervention	No. of patients/implants	No. of included studies	Survival rate (%)
Immediate placement and immediate loading	65/65	2	97.5
Immediate/early placement and conventional loading	106/106	4	93.6
Conventional placement and immediate/early loading	84/90	4	92.4
Conventional placement and conventional loading	244/248	11	92.8

SUCCESS AND FAILURE

Whether an implant succeeds or fails is related to several influenceable and non-influenceable factors. Operator skills and patient related factors, such as oral hygiene, health status, smoking habits and bone quality and quantity, may jeopardize directly or indirectly the osseointegration chances of the alloplast.

Various studies have found the success rates of implants to be between 74-99 % (Adell et al. 1981, Henry et al. 1996, Lindh et al. 1998, Weng et al. 2003, Davis et al. 2004, Misch et al. 2008). These diverse results may be partly explained by the different applied criteria for success. One clinician may label an implant with extensive marginal bone loss but still in place as successful, whereas another clinician, using defined criteria for success, would remove the same implant to prevent risk of further damage to the host bone (Albrektsson & Zarb 1998). In this, it is crucial to remark the difference between surviving implants and successful implants. The term surviving refers to those implants that are still in the jaw of the patient regardless of their condition. On the other hand, implants will only be categorized as successful when they meet specific success criteria. The consequence of these criteria for success is indissolubly coupled with associated criteria for failure. In the past these criteria for implant failure were usually related to integration problems.

Implant success

Smith & Zarb (1989) extended the earlier proposed criteria of Albrektsson (1986), and ended up with the following six criteria to determine the clinical success of endosseous dental implants:

1. The individual unattached implant is immobile when tested clinically. It should be a two point scale which indicates whether the implant is mobile or not. Clinical research in osseointegration indicates that when mobility occurs the implant is surrounded by connective tissue. The implant becomes tender to percussion or pressure. Thus, mobility is considered a clear sign of failure.
2. A radiograph of the implant does not demonstrate evidence of peri-implant radiolucency at any part of the dental implant. In some ways peri-implant

radiolucency and mobility may measure the same aspects. However, it is possible, that an implant shows a partial peri-implant radiolucency with no mobility.

3. The mean vertical bone loss should not exceed 0.2 mm annually after the first year of service. These marginal bone changes can be evaluated in time on the basis of properly made radiographs.
4. The implant cannot be the cause of persistent pain, infections or any discomfort to the patient. However, this criterion should be interpreted with cautiousness. Pain and discomfort due to nerve damage during the surgical procedure are iatrogenic complications and should be considered neither a success nor a failure in determining success.
5. The implant should allow the placement of a restoration with an esthetic appearance that is satisfactory to the clinician and the patient.
6. Dental implants should not merely be successful for one or two years after placement, but their success should also be based on long-term follow-up. A success rate of 85 % at the end of a 5-year observation period and 80 % at the end of a 10-year period are minimum levels for success.

Restorative success

Whether an implant treatment succeeds or fails is not only related to the success of osseointegration. Apart from the above-described success criteria for osseointegration, time-dependent restorative treatment outcomes are the determinant of overall success when using dental implants. The ultimate goal of the practitioner should be a successful rehabilitation of the patient in the short and long term. Obviously, since different suprastructures require different numbers of implants, the outcome of certain restorative designs is dictated by successful individual or multiple implant osseointegration. Failure of one or more implants may result in subtle or profound restorative outcomes (Albrektsson & Zarb 1998).

Other failures may be related to complications concerning the suprastructure. These may include minor adjustments, such as polishing chipped-off porcelain, to incidents making moderate interventions (for example: recementation of a loose crown, re-tightening of a loose screw) and major interventions necessary (for example: new crowns or abutments). Although these technical complications do not necessarily lead to implant loss or prosthetic failure, they can be a burden of maintenance and repair for the patient as the clinician and influence the satisfaction of both (De Boever et al. 2006).

Esthetic success

As the current implant survival and success rates achieve quite high results (Avivi-Arber & Zarb 1996, Haas et al. 2002, Blanes et al. 2007), the interest of clinicians and patients is more and more directed towards esthetics. Therefore, a significant part of implant success is nowadays dictated by the appearance of the soft tissues (Garber 1996, Levin et al. 2005).

Yet, a number of variables are responsible for the 'natural' appearance of implant-supported restorations. In recent years the concepts of implant placement have evolved from being mainly bone-driven towards biologically-driven, which pursues integration of the implant with the hard tissues (*i.e.* osseointegration) and soft tissues, hereby optimizing function and esthetics. The level of the peri-implant soft tissue margin, which influences the crown length, and its texture and color are decisive for the esthetic appearance of the single-tooth implant-supported replacement (Chang et al. 1999). In view of the necessity to quantify the esthetic outcome, Fürhauser and colleagues (2005) defined and evaluated the pink esthetic score (PES). This objective score assesses different aspects of the peri-implant soft tissues, and may as such objectify the soft tissue esthetic outcome of different surgical or restorative treatment procedures. Recently, in line with this pink esthetics score, a white esthetic score (WES) has been defined to evaluate the different esthetic aspects of the visible part of the crown restoration (Belser et al. 2009).

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Chapter 2

Immediate single-tooth implant-supported restoration in the premaxilla: a review of the literature

Single-tooth replacement in the anterior maxilla by means of immediate implantation & provisionalisation: a review

De Rouck, T., Collys, K. & Cosyn, J.

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ABSTRACT

Objectives: The objective of the present study was to assess to what extent the outcome of immediate implantation and provisionalization for replacing single maxillary teeth in the esthetic zone is favorable and predictable from a biologic as from an esthetic point of view.

Material and methods: An electronic (MEDLINE and Cochrane Oral Health Group Specialized Trials Register) and a manual search were performed to detect studies concerning maxillary single-tooth replacements by means of dental implants immediately placed into fresh extraction sockets and provisionalized within the first 24 hours. Only full-text reports on clinical studies published in English up to June 2006 were included. Case reports and reviews on the topic of interest were excluded.

Results: 11 studies were selected. Based on a qualitative data analysis implant survival and even managing papilla levels seem predictable following immediate implantation and provisionalization. However, maintaining the midfacial gingival margin may be more problematic since post-extraction bone remodeling and therefore marginal gingival changes will occur irrespective of the placement of an implant. The long-term impact of this observation is currently unclear and needs to be elucidated in future research.

Conclusions: The clinician is recommended to be reserved when considering immediate implant placement and provisionalization for replacing single maxillary teeth in the anterior zone. At the very least, a number of guidelines and prerequisites need to be taken into consideration.

INTRODUCTION

In many clinical cases of single tooth loss the implant restoration has become the treatment of choice (Jemt et al. 1990, Schmitt & Zarb 1993, Ekfeldt et al. 1994, Laney et al. 1994, Andersson et al. 1995, Henry et al. 1996, Belser et al. 2000). Its high predictability from a functional and esthetic point of view may account for this. Traditional guidelines advise that 2 to 3 months of alveolar ridge remodeling following tooth extraction and a supplementary 3 to 6 months of load-free healing are essential for implant osseointegration (Albrektsson et al. 1981, Brånemark 1983). Despite the benefits of implants for replacing missing teeth, this time consuming protocol is a disadvantage and may influence the decision to rehabilitate by means of dental implants. To reduce healing time immediate implant placement into fresh extraction sockets has been described in several studies. Providing good primary stability of these implants can be achieved, comparable survival rates to implants placed according to the original protocol may be expected (Becker & Becker 1990, Becker et al. 1991, Tolman & Keller 1991, Gelb 1993, Polizzi et al. 2000, Gomez-Roman et al. 2001). Besides immediate implantation, the time gain may be further optimized by reducing or even eliminating the load-free healing period following implant placement. Several investigators demonstrated successful immediate loading in edentulous mandibles by means of a fixed cross-arch splinted superstructure (Salama et al. 1995, Schnitman et al. 1997, Tarnow et al. 1997, Randow et al. 1999). Their promising results have led to further studies concentrating on the progressive shortening of the healing period for maxillary multi-unit implant reconstructions (Bergkvist et al. 2005, Degidi et al. 2005, Ibanez et al. 2005, Östman et al. 2005) and for single-tooth implants ultimately resulting in the immediate connection of an implant-retained provisional restoration (Ericsson et al. 2000, Chaushu et al. 2001, Cooper et al. 2001, Andersen et al. 2002).

Apart from time gain, another rationale for immediate implantation and provisionalization is the potential to maximally preserve hard and soft tissues, which may be beneficial to the esthetic treatment outcome. That is, post-extraction healing and healing from implant insertion coincide as there is only one surgical phase. Alternatively, the standard protocol with 2 to 3 consecutive surgeries in the same site may result in more tissue damage and loss. In addition, as the original gingiva may be preserved by the instant connection of a provisional restoration offering a mechanical support to the papillae and midfacial gingival tissues, the need for additional soft tissue surgery may be eliminated.

The objective of the present study was to assess the outcome of immediate implantation and provisionalization to replace single maxillary teeth in the esthetic zone. Specific emphasis is focused on predictability from a biologic and esthetic point of view.

MATERIAL AND METHODS

Study selection

Only full text reports on clinical studies published in English that enclosed maxillary single-tooth replacements by means of dental implants immediately placed into fresh extraction sockets and provisionalized within the first 24 hours were reviewed. In order to be as inclusive as possible, study duration was not considered as a selection criterion. Search results were excluded for one or more of the following reasons: case reports, reviews, reports without actual data or papers in which it was difficult to distinguish immediate from delayed implantation or upper from the lower jaw.

Outcome variables

The outcome variables of interest were implant survival rate and changes in peri-implant hard and soft tissue levels.

Search strategy

An electronic search was made in the MEDLINE and Cochrane Oral Health Group Specialized Trials Register databases dating back to 1977 and using October 2006 as the final date. The following combination of free text words and MeSH* terms was adopted:

Dental-Implants, Single-Tooth AND Maxilla* AND (immediate OR immediate placement OR immediate implantation) AND (provisionalisation OR provisionalization OR immediate loading)*

To minimize publication bias, a complementary manual search which included a revision of the past decade up to October 2006 was made of the following journals: *Clinical Oral Implants Research* and *International Journal of Oral and Maxillofacial Implants*. Additionally, reference lists of the articles retrieved following a preliminary selection by the electronic and manual search were scrutinized.

Assessment of the methodological quality

The methodological quality of the papers was assessed, mainly focusing on study design, description of patient's demographics and outcome variables measured.

Qualitative data analysis

The data were analyzed from a descriptive point of view as only a limited number of studies in reference to the topic was retrieved and considerable heterogeneity was found between them.

RESULTS

Search results

All search strategies provided 43 articles after eliminating titles that were present in different searches. From the 43 articles finally obtained, 11 were considered valid and 32 were excluded for the following reasons:

Implantation into healed sites (17 articles) (Gomes et al. 1998, Kupeyan & May 1998, Chaushu & Chaushu 2001, Jo et al. 2001, Andersen et al. 2002, Proussaefs et al. 2002, Rocci et al. 2003, da Cunha et al. 2004, Proussaefs & Lozada 2004, Schwartz-Arad & Levin

2004, Locante 2004, Abboud et al. 2005, Nuzzolese 2005, Ottoni et al. 2005, Park et al. 2005, Sudbrink 2005, Lindeboom et al. 2006)

No differentiation between immediate or delayed implantation and upper or lower jaw (7 articles) (Jo et al. 2001, Schwartz-Arad & Levin 2004, Locante 2004, Abboud et al. 2005, Ottoni et al. 2005, Toljanic & Baer 2005, Degidi et al. 2006)

Case reports (16 articles) (Gomes et al. 1998, Kupeyan & May 1998, Kan & Rungcharassaeng 2000, Chaushu & Chaushu 2001, Locante 2001, Garber et al. 2001, Touati & Guez 2002, Schiroli 2003, Leary & Hirayama 2003, Fugazzotto 2004, Mankoo 2004, Nuzzolese 2005, Park et al. 2005, Sudbrink 2005, Guirado et al. 2005, Tselios et al. 2006)

Review articles (3 articles) (Belser et al. 2004, del & Drago 2005, Attard & Zarb 2005)

Use of a non-standard implant design (expandable implant) (1 article) (Jo et al. 2001)

Reports merely providing clinical guidelines without actual data (5 articles) (Kan & Rungcharassaeng 2000, Locante 2001, Garber et al. 2001, Touati & Guez 2002, Mankoo 2004)

Methodological quality of included studies

In table 2.1 a summary is given of the experimental characteristics and results of all included studies. In 3 studies, the reasons for tooth loss were provided (Kan et al. 2003, Lorenzoni et al. 2003, Ferrara et al. 2006), whereas in 8 reports this information was lacking or not specified for the individual cases (Wöhrle 1998, Chaushu et al. 2001, Hui et al. 2001, Calvo Guirado et al. 2002, Groisman et al. 2003, Norton 2004, Cornelini et al. 2005, Tsirlis 2005). Five prospective studies on a single treatment strategy were included: Kan and co-workers (2003) treated 35 patients by means of maxillary immediate implantation and provisionalisation and 14 consecutive patients underwent the same treatment in the report of Wöhrle (1998). 19 patients in the report by Cornelini and co-workers (2005) were similarly treated, whereas an additional 3 received single teeth implants in the mandible. The study of Ferrara et al. (2006) included 33 consecutive patients receiving the same treatment protocol and Groisman and co-workers (2003) investigated 92 single-tooth maxillary implants. 6 prospective studies including data on immediately provisionalized single-teeth implants which had been placed into fresh extraction sockets or into healed sites, were also considered (Chaushu et al. 2001, Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003, Norton 2004, Tsirlis 2005). Among them, 2 were controlled clinical studies comparing immediate to delayed implantation (Norton 2004, Tsirlis 2005). Others pooled the data on both strategies in expressing results (Chaushu et al. 2001, Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003). Even though these reports have their merit from an exploratory point of view, they may add little valuable information on the outcome of the treatment concept of interest as there is lack in homogeneity of study samples. In addition, two reports included data on adjacent teeth immediately replaced by means of provisionally restored dental implants (Chaushu et al. 2001, Lorenzoni et al. 2003). Needless to say, tissue alterations between 2 implants on one hand and between a tooth and an implant on the other hand may differ substantially (Tarnow et al. 1992, Salama et al. 1998, Tarnow et al. 2000).

In all studies the concept of immediate non-occlusal loading was pursued. That is, provisional restorations were cleared of all contact in centric occlusion and during eccentric movements to avoid full functional loading of the implant during healing. In 9 studies cemented provisional restorations were used for this purpose (Wöhrle 1998, Chaushu et al. 2001, Hui et al. 2001, Calvo Guirado et al. 2002, Groisman et al. 2003, Kan et al. 2003, Lorenzoni et al. 2003, Norton 2004, Ferrara et al. 2006), whereas in 2 reports screw-retained provisionals were placed to avoid any chemical interference with the early stages of the healing process (Cornelini et al. 2005, Tsirlis 2005).

Only 5 authors published results on consecutively treated cases (Wöhrle 1998, Chaushu et al. 2001, Kan et al. 2003, Norton 2004, Ferrara et al. 2006). Even though this is of the utmost importance when interpreting results, the information was not provided or unclear in 6 reports (Hui et al. 2001, Calvo Guirado et al. 2002, Groisman et al. 2003, Lorenzoni et al. 2003, Cornelini et al. 2005, Tsirlis 2005).

In 3 studies the observation period was 12 months (Calvo Guirado et al. 2002, Kan et al. 2003, Cornelini et al. 2005). Tsirlis et al. (2005) published 2-year results on immediate implantation and provisionalization. Others included data on ongoing cases with a variable follow-up period ranging from 1 to 52 months (Wöhrle 1998, Chaushu et al. 2001, Hui et al. 2001, Groisman et al. 2003, Lorenzoni et al. 2003, Norton 2004, Ferrara et al. 2006). Since the time points of data collection differed with results after 1 year, 2 years, data corresponding to the last check-up visit or to the installation of the permanent crown, it is difficult to compare the outcome of the included studies. Cautiousness in comparing data seems also imperative since different implant types were used. In 2 studies screw-type cylindric implants (Calvo Guirado et al. 2002, Norton 2004) were inserted, whereas in another 4 screw-type tapered implant (Groisman et al. 2003, Kan et al. 2003, Cornelini et al. 2005, Tsirlis 2005) were used. In 2 studies both were placed (Wöhrle 1998, Hui et al. 2001). Two other reports described the use of stepped screw-type tapered implants (Lorenzoni et al. 2003, Ferrara et al. 2006). Finally, press-fit cylindric implants were inserted in one study (Chaushu et al. 2001). Besides morphology, implants differed in material: 7 used surface treated titanium implants (Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003, Norton 2004, Cornelini et al. 2005, Tsirlis 2005, Ferrara et al. 2006), 3 used hydroxyapatite-coated implants (Chaushu et al. 2001, Groisman et al. 2003, Kan et al. 2003) and one used both (Wöhrle 1998). In 5 studies, the use of a bone filler was used to fill the gap between the buccal socket wall and the implant (Chaushu et al. 2001, Hui et al. 2001, Groisman et al. 2003, Tsirlis 2005, Ferrara et al. 2006).

In most studies patient's demographics were well described. Only Groisman et al. (2003), Lorenzoni et al. (2003) and Wöhlre et al. (1998) did not provide data on the age range of the examined population. In some studies patients with smoking habits (Chaushu et al. 2001, Kan et al. 2003, Lorenzoni et al. 2003, Ferrara et al. 2006) and bruxism (Hui et al. 2001, Kan et al. 2003, Lorenzoni et al. 2003, Cornelini et al. 2005, Ferrara et al. 2006) were excluded. Remarkable is the fact that none of the investigators made notice of the gingival biotype in describing the profile of the included patients. Still, it has been documented that gingival levels are influenced by their biotype. That is, patients with a thin-scalloped gingival biotype are more prone to develop gingival recessions as compared to those with a thick-flat biotype (Müller & Eger 1997, Hammerle et al. 2004).

All investigators recorded implant survival rate. As an attempt was made to describe the amount of peri-implant bone loss, exact data concerning the latter were only provided in 5 articles (Kan et al. 2003, Lorenzoni et al. 2003, Norton 2004, Cornelini et al. 2005, Tsirlis 2005). Recordings of esthetic outcome variables were scarce: data on changes in peri-implant mucosa levels were found in 2 studies (Kan et al. 2003, Cornelini et al. 2005). Kan et al. (2003) described changes in papillae and midfacial gingival levels in reference to a line connecting the midfacial gingival levels of the 2 adjacent teeth. This was performed on the basis of color slides taken by hand-held photography. Cornelini and co-workers (2005) adopted the same technique to describe variations in midfacial gingival levels; yet, data were collected at chairside. An ordinal-scaled index (Jemt's index (1997)) was used to document papilla height.

Treatment outcome from a biologic viewpoint: implant survival rate

Table 2.1 summarizes the outcome of the treatment strategy of interest for each of the included studies. An implant survival rate of 100% in the short term was described in all but three studies: Chaushu and co-workers (2001) achieved osseointegration in only 78.6% of the cases, whereas Ferrara and co-workers (2006) achieved 93.9% and Groisman and co-workers (2003) reported 93.5%.

Treatment outcome from an esthetic viewpoint: hard and soft tissue changes

Scrutinizing the results in table 2.1 on immediately placed and provisionally restored single tooth maxillary implants indicates a mean peri-implant bone loss ranging from 0.2 mm to 0.5 mm at 1 year follow-up (Kan et al. 2003, Norton 2004, Cornelini et al. 2005). Several implants in the study by Kan et al. (2003) showed bone gain, which is in accordance with findings from Norton and co-workers (2004) who described no bone loss to bone gain in 37.5% of the implants placed according to the immediate implantation and provisionalization protocol. Note that the mean bone loss of 0.75 mm after 12-14 months of follow-up in the study by Lorenzoni et al. (2003) relates to as well immediately placed implants as to implants inserted into healed sites. The study of Tsirlis et al. (2005) yielded an average peri-implant bone loss of 0.75 mm after a 2-year observation period.

Two research centers published one-year data on soft tissue changes following immediate implantation and provisionalization. Kan et al. (2003) reported a mean loss in papilla height between 0.39 mm and 0.53 mm. In the study by Cornelini and co-workers (2005) 61% of the papillae received a score 2 according to the Jemt's index (1997) (at least half of the height of the papilla is present) and 39 % presented a score of 3 (the papilla fills up the entire proximal space) at study termination. It is not clear from the study, however, how these scores relate to the height of the papillae prior to removal of the tooth. An average midfacial gingival recession between 0.55 mm and 0.75 mm can be expected after one year follow-up (Kan et al. 2003, Cornelini et al. 2005).

DISCUSSION

The concept of immediate implantation and provisionalization for replacing single teeth in the premaxilla comes with some obvious benefits: as it combines tooth extraction, implant surgery and restorative treatment, the time gain can be optimized. At least from a theoretical point of view, hard and soft tissues may be maximally preserved since there is only one surgical phase and a provisional restoration offers an instant mechanical support to the papillae and midfacial gingival tissues.

Table 2.1 Experimental characteristics & results of clinical studies on immediate implantation & provisionalization for replacing single maxillary teeth in the esthetic zone

Author	Number of implants	Observation period	Implant type	Minimal insertion torque	Results		
					Implant survival rate	Hard tissue changes	Soft tissue changes
Wöhrle 1998	14	9 – 36 months	Screw-type cylindric & screw-type tapered	45 Ncm	100 %	Max. 1 mm peri-implant bone loss †	Pre-implant status = implant status
Chaushu et al. 2001	14 (8*)	6 – 18 months	Press-fit cylindric	No data	78.6 %	Peri-implant bone loss did not extend beyond implant-abutment connection †‡	No data
Hui et al. 2001	13 (11*)	1 – 15 months	Screw-type cylindric & screw-type tapered	40 Ncm	100 %	Max. 0.6 mm peri-implant bone loss †‡	No data
Calvo Guirado et al. 2002	9 (9*)	12 months	Screw-type cylindric	15 Ncm	100 %	Peri-implant bone loss to the first thread ‡	No data
Kan et al. 2003	35	12 months	Screw-type tapered	No data	100 %	Peri-implant bone loss: Mesial: 0.26 ± 0.40 mm Distal: 0.22 ± 0.28 mm	Soft tissue loss: Mesial: 0.53 ± 0.39 mm Distal: 0.39 ± 0.40 mm Midfacial: 0.55 ± 0.53 mm
Groisman et al. 2003	92	6 – 24 months	Screw-type tapered	No data	93.5 %	Max. 2 mm of bone loss†	3 implants with more than 2 mm buccal soft tissue loss
Lorenzoni et al. 2003	8 (4*)	12 – 14 months	Stepped screw-type tapered	32 Ncm	100 %	Peri-implant bone loss: 0.75 ± 0.50 mm ‡	No data
Norton 2004	16 (12*)	13 – 30 months	Screw-type cylindric	25 Ncm	100 %	Peri-implant bone loss: 0.22 ± 0.41 mm †	No data
Cornelini et al. 2005	19 (3°)	12 months	Screw-type tapered	No data	100 %	Peri-implant bone loss: 0.50 mm §	Midfacial soft tissue loss: 0.75 mm §
Tsirlis 2005	28 (15*)	24 months	Screw-type tapered	No data	100 %	Peri-implant bone loss: 0.75 ± 1.05 mm	No data
Ferrara et al. 2006	33	12 – 52 months	Stepped screw-type tapered	No data	93.9 %	No apparent bone loss	No Data

* Delayed implant placement
° Mandibular implants
† Peri-implant bone loss assessed on most recent radiographs
‡ Overall peri-implant bone loss on immediate as on delayed inserted implants
§ Overall peri-implant bone / soft tissue loss on maxillary as on mandibular implants

In the past, osseointegration as determined by implant survival was the main criterion for success of any implant-supported restoration. From such a viewpoint, it seems that immediate implantation and provisionalization is a satisfactory and predictable treatment concept since all but three studies yielded 100% implant survival. This success rate is at least comparable to data published for single-tooth implants placed according to the standard protocol in healed sites (Goodacre et al. 1999). Still, one should be aware that the promising results in this review article only relate to a limited number of implants that may not have been necessarily all consecutive cases. The low implant survival rate of 78.6% described by Chaushu and co-workers (2001) for immediate implantation and provisionalization may have been the result of using press-fit implants.

As the criteria for success have changed during the past decade in the interest of an esthetic treatment outcome, implant dentistry has strongly evolved from a bone-driven surgical protocol to a restoratively- and biologically-driven protocol. To optimize esthetics, preservation of hard and soft peri-implant tissues is mandatory. The results of this study on immediately placed and provisionally restored single tooth maxillary implants indicate a mean peri-implant bone loss between 0.2 mm and 0.5 mm at 1 year follow-up (Kan et al. 2003, Cornelini et al. 2005) with ongoing loss thereafter reaching an average 0.75 mm crestal bone loss at 2 years follow-up according to one study (Tsirlis 2005). These data seem lower as compared to earlier published data on submerged implants showing peri-implant bone loss of about 1 mm during the first year (Adell et al. 1986, Jemt & Pettersson 1993, Laney et al. 1994, Andersson et al. 1995, Goodacre et al. 1999). Hence, the concept of immediate implantation and provisionalization seems at least as favorable as the standard protocol in preserving hard tissues, at least in the short term. Still, as advantageous this observation may be, the key point in maintaining interdental papillae may be the bone level to the adjacent tooth. Providing this bone peak is preserved during extraction of the hopeless tooth and during implant surgery, the papilla height can be secured (Tarnow et al. 1992, Salama et al. 1998, Choquet et al. 2001, Buser et al. 2004). Hence, the results described by Kan et al. (2003) and Cornelini et al. (2005) on the limited loss of papilla height following immediate implantation and provisionalization should not be that surprising as they may be more related to the presence of the bone peak to the adjacent tooth than to the surgical and/or restorative strategy by itself. At least when comparing early to delayed placement of single-tooth implants, it has been shown there is no difference in papilla height after 1.5 years of follow-up (Schropp et al. 2005).

Even though it was previously believed that implant placement into fresh extraction sockets would prevent remodeling and hence maintain the original shape of the ridge (Paolantonio et al. 2001), recent reports have failed to support this (Botticelli et al. 2004, Araujo et al. 2005, Araujo & Lindhe 2005). Animal and human studies have shown that irrespective of the placement of an implant, post-extraction bone remodeling will occur resulting in horizontal and vertical loss (Botticelli et al. 2004, Araujo et al. 2005, Araujo & Lindhe 2005). In addition, bone loss will be more pronounced on the buccal than on the lingual aspect of the ridge. This is explained by the fact that the buccal bone crest is solely comprised of bundle bone which entirely resorbs following tooth removal. In contrast, the lingual crest is built up by cortical bone on the outer surface preventing excessive loss. Needless to say, these inevitable bone changes may be detrimental for the management of the midfacial gingival margin when implants are placed into fresh extraction sockets. Although currently available studies report a limited midfacial gingival recession between 0.55 mm and 0.75 mm at one year follow-up (Kan et al. 2003, Cornelini et al. 2005), lack of long-term results make conclusions still premature. In addition, these one-year data have been described in reference to a line connecting the midfacial gingival levels of the 2 adjacent teeth. Since this line is not necessarily stable over time as it is subjected to the healing process, inflammation etc. a standardized measuring technique using fixed reference points would be preferable in future research. In light of these observations and comments, immediate implant placement should not be the treatment concept of choice for patients with a thin-scalloped gingival biotype in which buccal bone resorption may easily result in excessive midfacial gingival recession. In these high-risk patients, a staged procedure is more predictable and therefore preferable. In contrast, the risk for esthetic failure may be limited in patients with a thick-flat biotype. Here immediate implant placement can be considered. Still, we believe that in the interest of a predictable esthetic treatment outcome for these patients in the long run, implant surgery should include filling the marginal void between the implant and the buccal socket wall using a bone filler with a low substitution rate until this procedure is shown redundant by controlled clinical studies. Another guideline when considering immediate implant placement and provisionalization is the use of surface-treated implants as these provide the highest bone-to-implant contact which is beneficial to rapid osseointegration (Brunski 1992, Wennerberg et al. 1995, Wong et al. 1995, Klokkevold et al. 1997, Wennerberg et al. 1997, Lazzara et al. 1999). In addition, it is easier to achieve primary stability using screw-type tapered implants instead of screw-type cylindrical implants. Still, there has been no consensus yet on the minimal insertion torque for the treatment concept discussed in this paper.

As these guidelines may be valuable in clinical practice, case selection remains of the utmost importance. That is, there are a number of prerequisites that need to be fulfilled when immediate implantation and provisionalization are considered for replacing single maxillary teeth in the esthetic zone. First, immediate implant placement may be adversely affected by the presence of infection (Chen et al. 2004). In that case, more standard procedures should be followed. Second, establishing good primary stability must be a major concern as it is for the standard implant placement protocol. This can only be granted when long implants are used crossing the apical portion of the extraction socket. Thus, sufficient bone volume in this area is an important prerequisite. Third, immediate provisionalization should not be performed in case of buccal bone defects extending to the buccal crest. These situations require hard tissue grafting and the use of barrier membranes over the alveolar ridge making the connection of a restoration to the implant impossible at the time if even immediate implantation is performed. In addition, the extraction alveolus can complicate implant placement especially when the prosthetic superstructure obliges the surgeon to deviate from the axis of the alveolus. As this requires surgical skills, operator experience is another prerequisite. A final concern may be of restorative nature: occlusion and articulation might obstruct every intention to clear the provisional restoration of all contact. In these cases, the standard protocol should be followed.

In conclusion, the concept of immediate implantation and provisionalization for replacing single teeth in the premaxilla seems appealing for the clinician. Indeed, implant survival and even managing papilla levels seem predictable following this treatment strategy. This should not be surprising as these variables are not primarily influenced by the surgical/restorative procedure by itself. However, maintaining the midfacial gingival margin seems less predictable since post-extraction bone remodeling and therefore marginal gingival changes will occur irrespective of the placement of an implant. Since the currently available information on this topic is very scarce with a total lack of long-term results, the clinician should be reserved when considering immediate implant placement and provisionalization for replacing single maxillary teeth in the esthetic zone. At the very least, a number of guidelines and prerequisites need to be taken into consideration. More long-term prospective and controlled clinical studies are mandatory to document the esthetic treatment outcome of this treatment strategy. In addition, a standardized technique to measure changes in gingival levels is promoted in future research.

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Chapter 3

Objectives

The main objective of the present thesis was to assess the short-term esthetic outcome of immediate single-tooth implant restorations in the anterior maxilla. Specific emphasis is focused on predictability from a biologic and esthetic point of view.

Key questions in this respect relate to patient selection (a), implant selection (b) and treatment protocol (c-e):

- (a) Low-risk patients for esthetic failure show a so-called 'thick-flat gingival biotype', whereas high-risk patients present a 'thin-scalloped gingival biotype'. What is the prevalence of these morphotypes in a large group of young adults using simple diagnostic methods (chapter 4)?
- (b) What is the rationale for using tapered titanium implants with a micro-rough body and a turned collar (chapter 5)?
- (c) What is the clinical outcome of immediate single-tooth implants in the anterior maxilla in well-selected patients (chapter 6)?
- (d) What is the impact of the restorative procedure on the esthetic treatment outcome of immediate single-tooth implants in the anterior maxilla (chapter 7)?
- (e) How should immediate single-tooth implants be provisionally restored and what is the motivation for this method (chapter 8)?

Chapter 4

The gingival biotype,
a crucial factor for patient selection

The gingival biotype revisited

Transparency of the periodontal probe through the gingival margin as a method to discriminate thin from thick gingiva

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ABSTRACT

Objectives: To detect groups of subjects in a sample of 100 periodontally-healthy volunteers with different combinations of morphometric data related to central maxillary incisors and surrounding soft tissues.

Material and methods: 4 clinical parameters were included in a cluster analysis: crown width / crown length ratio (CW/CL), gingival width (GW), papilla height (PH) and gingival thickness (GT). The latter was based on the transparency of the periodontal probe through the gingival margin while probing the buccal sulcus. Every first volunteer out of ten was re-examined to evaluate intra-examiner repeatability for all variables.

Results: High agreement between duplicate recordings was found for all parameters, in particular for GT pointing to 85 % ($\kappa = 0.70$; $p = 0.002$). The partitioning method identified 3 clusters with specific features. Cluster A1 (9 males, 28 females) displayed a slender tooth form (CW/CL = 0.79), GW of 4.92 mm, PH of 4.29 mm and a thin gingiva (probe visible on one or both incisors in 100 % of the subjects). Cluster A2 (29 males, 5 females) presented similar features (CW/CL = 0.77; GW = 5.2 mm; PH = 4.54 mm) except for GT. These subjects showed a clear thick gingiva (probe concealed on both incisors in 97 % of the subjects). The third group (cluster B: 12 males, 17 females) differed substantially from the other clusters in many parameters. These subjects showed a more quadratic tooth form (CW/CL = 0.88), a broad zone of keratinized tissue (GW = 5.84 mm), low papillae (PH = 2.84 mm) and a thick gingiva (probe concealed on both incisors in 83 % of the subjects).

Conclusions: The present analysis using a simple and reproducible method for GT assessment confirmed the existence of gingival biotypes. A clear thin gingiva was found in about one third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced ‘thin-scalloped biotype’ (cluster A1). A clear thick gingiva was found in about two thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced ‘thick-flat biotype’ (cluster B). The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop (cluster A2).

INTRODUCTION

Earlier reports showed that the clinical appearance of healthy periodontal tissues differs from subject to subject (Olsson & Lindhe 1991). The bulky, slightly scalloped marginal gingiva with short and wide teeth on one hand and the thin, highly scalloped marginal gingiva with slender teeth on the other, may serve to illustrate the existence of markedly different periodontal entities or so-called 'gingival biotypes' (Weisgold 1977, Seibert & Lindhe 1989). The identification of the gingival biotype may be important in clinical practice since differences in gingival and osseous architecture have been shown to exhibit a significant impact on the outcome of restorative therapy (table 4.1). At natural teeth, Pontoriero & Carnevale (2001) showed more soft tissue regain following crown lengthening procedures in patients with a so-called 'thick-flat biotype' than in those with a 'thin-scalloped biotype'. This observation is in line with a higher prevalence of gingival recession in the latter as reported by Olsson & Lindhe (1991). Also at implant restorations, the gingival biotype has been described as one of the key elements decisive for a successful treatment outcome (Kois 2004). In particular, papilla presence between immediate single-tooth implants and adjacent teeth was significantly correlated with a thick-flat biotype (Romeo et al. 2008). In addition, a trend towards more gingival recession at immediate single-tooth implant restorations in patients with a thin-scalloped biotype was described (Evans & Chen 2008). Also the outcome of regenerative surgery seems negatively influenced by the thickness of the soft tissues (Anderegg et al. 1995, Baldi et al. 1999). These observations illustrate that disparities in esthetic treatment outcome could arise as a result of variability in tissue response to surgical trauma. The use of simple and reliable methods to identify the gingival biotype in clinical practice would be advantageous as this could help to tune the treatment for the individual and predict its specific outcome.

Table 4.1. Tissue response to inflammation, surgery and tooth extraction (Kao et al. 2008)

	Thick gingival biotype	Thin gingival biotype
Inflammation	Soft tissues: marginal inflammation with pocket formation, bleeding on probing, oedema	Soft tissues: gingival recession without pocket formation
	Hard tissues: formation of infrabony defects	Hard tissues: loss of the thin vestibular bone plate
Surgery	Predictable hard and soft tissue healing	Delicate and unpredictable tissue healing (recession)
Tooth extraction	Minimal ridge resorption	Extensive ridge resorption in the apical and lingual direction

Hitherto, a limited number of studies based on relatively small samples have been published using cluster analysis to identify subject groups with different combinations of morphometric data related to tooth and gingiva characteristics (Müller & Eger 1997, Müller et al. 2000a). In these studies, gingival thickness (GT) was determined using an ultrasonic device. Although this non-invasive method proved to be reproducible (Eger et al. 1996), drawbacks include difficulties in maintaining the directionality of the transducer (Daly & Wheeler 1971), unavailability of the device (Vandana & Savitha 2005) and high costs. These factors may be responsible for the fact that the device has not become part of the standard armamentarium of the clinician. Recently, a simple method has been proposed to discriminate thin from thick gingiva based on the transparency of the periodontal probe through the gingival margin (Kan et al. 2003). The objective of the present study was to identify the existence of gingival biotypes in a large sample of periodontally-healthy volunteers using this visual method for GT assessment.

MATERIAL AND METHODS

Subjects

This study included clinical data on 100 medical students of the Free University in Brussels (VUB). Volunteers having all maxillary front teeth were included. Exclusion criteria were as follows:

(i) Subjects with crown restorations or fillings involving the incisal edge on anterior maxillary teeth,

(ii) Pregnant or lactating female volunteers,

(iii) Subjects taking medication with any known effect on the periodontal soft tissues,

(iv) Volunteers with clinical signs of periodontal disease defined as having pockets exceeding 3 mm.

All subjects were provided with oral hygiene instructions and tooth polishing. This was preceded by calculus removal, if necessary. All subjects consented to participate.

Clinical parameters

Five clinical parameters were systematically recorded by one clinician at one week following oral hygiene instructions and dental cleaning:

1. Crown width / crown length ratio (CW/CL) of the right central incisor was determined according to Olsson & Lindhe (1991). Assessments of width and length were recorded to the nearest 0.1 mm using a caliper. The crown length was measured between the incisal edge of the crown and the free gingival margin, or if discernible, the cemento-enamel junction. The length of the crown was divided into 3 equal portions of equal height. Crown width, i.e. the distance between the approximal tooth surfaces, was recorded at the border between the middle and cervical portion.
2. Gingiva width (GW) was measured midfacially with a periodontal probe (CPU 15 UNC, Hu-Friedy®, Chicago, USA) to the nearest 0.5 mm. This parameter was defined as the distance from the free gingival margin to the mucogingival junction. Scores obtained from both central incisors were averaged.
3. Papilla height (PH) was assessed to the nearest 0.5 mm using the same periodontal probe at the mesial and distal aspect of both central incisors. This parameter was defined as the distance from the top of the papilla to a line connecting the midfacial soft tissue margin of the two adjacent teeth (Olsson et al. 1993). The mean value was calculated for the 3 papillae.
4. Gingival thickness (GT) was evaluated and categorized into thick or thin on a site level. This evaluation was based on the transparency of the same periodontal probe through the gingival margin while probing the sulcus at the midfacial aspect of both

central maxillary incisors (Kan et al. 2003). If the outline of the underlying periodontal probe could be seen through the gingiva it was categorized as thin (score: 0); if not, it was categorized as thick (score: 1). This resulted in 3 possible scores on a patient level: 0 (both central incisors with score 0), 1 (one central incisor with score 1) or 2 (both central incisors with score 1) (fig.4.1).

5. Probing depth (PD) was measured to the nearest 0.5 mm at the midfacial aspect of both central incisors.

Figure 4.1 Determination of GT using the periodontal probe.

Intra-examiner repeatability

The intra-examiner repeatability of the clinician who performed all clinical examinations was analyzed. Therefore, every first volunteer out of ten was re-examined 1 week after the first recording by the same clinician.

Statistical analysis

For all continuous variables (CW/CL, GW, PH) intra-examiner repeatability was evaluated using the Pearson's correlation coefficient. For GW and PH percentile agreement within 1 mm deviation was also calculated. Categorical variables (GT) were analyzed by means of percentile agreement and Cohen's κ statistics.

As already described mean values and standard deviations were calculated per subject for all continuous variables. Significant disparities between men and women were assessed using the independent samples *t*-test. The Fisher's exact test was adopted to evaluate the impact of gender on GT.

Cluster analysis based on Euclidian distances of 4 clinical parameters was used to detect groups in the morphometric data. A partition of 100 subjects into three clusters was iteratively improved by non-hierarchical disjunct cluster analysis using a k-mean algorithm in order to reduce the within-group sum of squares (Hartigan & Wong 1979). In the search for significant differences among the clusters one-way analysis of variance (continuous variables) and the Kruskal-Wallis test (categorical variables) were applied. Post hoc tests included the Scheffe's test, respectively the Mann-Whitney test corrected for multiple comparisons.

RESULTS

The study population consisted out of 100 periodontally healthy medical students. 50 male and 50 female Caucasian volunteers were examined, with a mean age of 28 years (SD 9; min 19; max 56). 16 % of the subjects were smokers.

Reproducibility of the measurements was evaluated in 10 volunteers. The Pearson's correlation coefficient revealed 0.948 ($p < 0.001$), 0.824 ($p < 0.001$) and 0.723 ($p < 0.001$) for respectively CW/CL, GW and PH. All but one measurement of the GW and 87 % of the assessed PH showed agreement within 1 mm deviation. The method to evaluate GT proved to be highly reproducible with 85 % agreement between duplicate measurements and a corresponding κ of 0.70 ($p = 0.002$).

Clinical parameters

Table 4.2 presents descriptive statistics of 4 clinical parameters. CW/CL was a reference for the crown form of the right central incisor and was on average 0.81. The mean GW was 5.29 mm, PH 3.96 mm and PD 1.40 mm. There were no significant differences between men and women for any of these parameters, although a trend was shown for PH ($p = 0.101$) and PD ($p = 0.097$).

The frequency distribution for GT is depicted in table 4.3. In more than half of the patients (57 %) the gingiva was thick enough to conceal the periodontal probe at both incisors (score 2). The data on GT were significantly different between men and women ($p < 0.001$): 78 % of the male participants displayed a score 2 corresponding to a clear thick gingiva, while only 36 % of the female participants showed this score.

Table 4.2. Clinical characteristics of tooth form and gingiva in 100 subjects (mean (SD))

	Male Participants	Female participants	Total	Min – max
Crown width / Crown length ratio	0.80 (0.11)	0.82 (0.11)	0.81 (0.11)	0.54 – 1.10
Gingival width (mm)	5.28 (0.88)	5.30 (0.93)	5.29 (0.90)	3.0 – 7.5
Papilla height (mm)	4.12 (0.95)	3.80 (0.97)	3.96 (0.97)	1.2 – 6.0
Pocket depth (mm)	1.47 (0.40)	1.32 (0.46)	1.40 (0.44)	0.50 – 2.75

Table 4.3. Frequency distribution for gingival thickness

	Male participants	Female participants*	Total
Score 0 (%)	10	46	28
Score 1 (%)	12	18	15
Score 2 (%)	78	36	57

*significant difference between male and female participants

Cluster analysis

The partitioning method identified 3 groups using the morphometric data obtained from the 100 participants. The specific features of each cluster are presented in table 4.4 and 4.5. Cluster A1 comprised 37 participants (9 men & 28 women), cluster A2 34 (29 men & 5 women) and cluster B 29 (12 men & 17 women).

Cluster A1 (fig.4.2) displayed a slender tooth form (CW/CL = 0.79), GW of 4.92 mm, PH of 4.29 mm and a thin gingiva (probe visible on one or both incisors in 100 % of the subjects). Cluster A2 (fig.4.3) presented similar features (CW/CL = 0.77; GW = 5.2 mm; PH = 4.54 mm) with no significant differences for these parameters in comparison to cluster A1 ($p \geq 0.281$). However, subjects of cluster A2 showed a clear thick gingiva (probe concealed on both incisors in 97 % of the subjects) ($p < 0.001$). A trend towards slightly deeper PD was also found in subjects of cluster A2 when compared to those of cluster A1 ($p = 0.095$).

29 participants comprising cluster B (fig.4.4) had a more quadratic tooth form (CW/CL = 0.88) when compared to subjects of cluster A1 ($p = 0.003$) and A2 ($p < 0.001$). More apical contact areas and significantly lower papilla levels (PH = 2.84 mm) in comparison to cluster A1 ($p < 0.001$) and A2 ($p < 0.001$) were in line with this observation. The mean GW of 5.84 mm in cluster B was significantly higher when compared to cluster A1 ($p < 0.001$) and A2 ($p = 0.014$). A significant disparity between cluster B and A1 was also found in terms of GT ($p < 0.001$): 83 % of the subjects of cluster B showed a clear thick gingiva. The mean PD of 1.55 mm for cluster B was significantly higher in comparison to cluster A1 ($p = 0.010$).

Table 4.4. Clinical characteristics of tooth form and gingiva (mean (SD)) per cluster

	Cluster A1	Cluster A2	Cluster B
Prevalence (%)	37	34	29
Crown width / Crown length ratio	0.79 (0.09)	0.77 (0.09)	0.88 (0.13)†*
Gingival width (mm)	4.92 (0.80)	5.20 (0.89)	5.84 (0.79)†*
Papilla height (mm)	4.29 (0.70)	4.54 (0.65)	2.84 (0.58)†*
Pocket depth (mm)	1.23 (0.40)	1.45 (0.39)	1.55 (0.47)*

†significant difference between cluster A2 & B

*significant difference between cluster A1 & B

Table 4.5. Frequency distribution for gingival thickness per cluster

	Cluster A1	Cluster A2†	Cluster B*
Score 0 (%)	73	0	3
Score 1 (%)	27	3	14
Score 2 (%)	0	97	83

†significant difference between cluster A1 & A2

*significant difference between cluster A1 & B

Figure 4.2 Clinical example of a subject of cluster A1.

Figure 4.3 Clinical example of a subject of cluster A2.

Figure 4.4 Clinical example of a subject of cluster B.

DISCUSSION

For a restoration to be a success, it should closely resemble what once existed in nature from a functional as from an esthetic point of view. Complete harmony and symmetry of a restoration with the surrounding soft tissues may be most challenging and can therefore be considered the ultimate goal in terms of esthetics. Evidently, insight into the morphological appearance of the periodontal structures and teeth is a prerequisite to accomplish this goal in a predictable way.

Previous studies have already shown considerable variation between individuals with regard to morphological characteristics of the periodontium and teeth. Already in 1989 the existence of distinct morphotypes - so-called 'periodontal biotypes' - was suggested (Seibert & Lindhe 1989). Later on, the specific features of these biotypes became well defined by Olsson et al. (1993). The objective of the present study was to evaluate if groups of subjects with different morphometric combinations truly exist in a large sample using simple diagnostic methods. We decided only to include central maxillary incisors as reference teeth because differences between biotypes are most explicit for these teeth and since their specific features are easily found in other parts of the dentition (Olsson & Lindhe 1991, Olsson et al. 1993, Müller et al. 2000a).

Only one parameter, notably GT, presented a significant difference between male and female subjects. That is, 84 % of all measured central incisors of male participants showed a gingiva which was thick enough to conceal the periodontal probe while probing the buccal sulcus. The equivalent value for females was only 45 %. This disparity could be expected since previous reports had already demonstrated a generally thinner masticatory mucosa for females (Müller et al. 2000b, Vandana & Savitha 2005).

Cluster analysis encompasses a number of different algorithms and methods for grouping data of similar kind into respective categories. Theoretically, any number up to 100 partitions could be generated by this exploratory approach; yet, the identification of more than 3 clusters resulted in partitions of questionable clinical meaning. We applied cluster analysis to categorize subjects with similar morphometric characteristics and identified 3 groups (cluster A1, A2 and B) with comparable number of individuals on the basis of 4 clinical parameters, i.e. CW/WL, GW, PH and GT. Our results indicated high intra-examiner repeatability for GT assessment substantiating the clinical usefulness of the simple method as proposed by Kan et al. (2003). By and large, cluster A1 and A2 showed similar tooth and gingiva characteristics. Specific features included slender teeth, a relatively narrow zone of keratinized tissue and a highly scalloped gingival margin. In cluster A1, the vast majority of the subjects showed a clear thin gingiva. Since our results showed a higher prevalence of a thin gingiva in female volunteers, it should not be surprising that cluster A1 mainly consisted of females. Interestingly, the characteristics of this cluster seemed to correspond to the features of the previously introduced 'thin-scalloped biotype' (Weisgold 1977, Seibert & Lindhe 1989).

In contrast to the subjects of cluster A1, those of cluster A2 were mostly male volunteers showing a clear thick gingiva. This observation failed to support the hypothesis that a slender tooth form always merges with a thin gingiva, which is in accordance with earlier reports. Olsson et al. (1993) described the lack of a significant relationship between CW/CL and GT. Also Eger et al. (1996) failed to observe a meaningful association between these parameters. In addition, a relationship between tooth shape and bone morphology could not be confirmed (Becker et al. 1997).

In the present study a third cluster could be identified (cluster B), in which subjects mainly presented a thick gingiva as in cluster A2. However, the other clinical parameters of cluster B differed substantially from the other clusters. Specific features included short and wide teeth, a broad zone of keratinized tissue and a flat, slightly scalloped gingival margin. These characteristics seemed to correspond to the features of the previously introduced ‘thick-flat biotype’ (Weisgold 1977, Seibert & Lindhe 1989). As a result, about two thirds of our sample (cluster A1 and B) showed high similarity with earlier defined gingival biotypes, whereas one third (cluster A2) with a clear thick gingiva could not be classified as such. This observation is imperative as it shows that a clear thick gingiva only comes in about half of the cases with quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin.

Former studies using cluster analysis also revealed three groups of subjects with different combinations of morphometric data related to maxillary front teeth and surrounding soft tissues (Müller & Eger 1997, Müller et al. 2000a). Both studies described groups which could be identified with some of the clusters in the present study. The subjects comprising cluster A and B in the study of Müller & Eger (1997) resembled those of respectively cluster A1 and B in this report. In the same manner we could identify cluster A1 and B in a subsequent report by Müller et al. (2000a), which presented comparable features with the similarly labeled clusters of the current study including their prevalence (A1: 35% and B: 28 % in the study by Müller et al. (2000a); A1: 37% and B: 29% in this study). Interestingly, the remaining third cluster in the studies showed little resemblance. In particular, cluster C in the report by Müller & Eger (1997), characterized by a thin and narrow gingiva at the maxillary front teeth in conjunction with a quadratic tooth form, could neither be identified with cluster A2 in their subsequent report (Müller et al. 2000a), nor with the features of cluster A2 in the present study. The fact that the conditions of two groups of the current study (cluster A1 and B) can be compared with those of two groups in earlier studies may confirm the existence of two biotypes within a population. At the same time it is clear that about one third of the population cannot be classified in a uniform way given the observed inconsistencies. This observation highlights a possible impact of racial and genetic variation on the morphology of teeth and soft tissues (Vandana & Savitha 2005). In addition, the influence of the bucco-lingual tooth position within the alveolar process should not be underestimated. In fact, Müller & Könönen (2005) showed that most of the variation in GT was related to this position and only to a minor extent to subject variability (*i.e.* thin-scalloped and thick-flat biotype).

In the present study low midfacial pocket depth was systematically recorded, which should not be surprising since only periodontally-healthy patients were included. Still, the observed disparity in pocket depth between the clusters remained noteworthy. At buccal surfaces the mean value increased gradually from 1.23 mm (cluster A1) over 1.45 mm (cluster A2) to 1.55 mm (cluster B). A statistically significant difference between cluster A1 and B was found, which may have been the result of a high sample size. The clinical relevance of this difference, however, seems negligible and the proximity of the mean data suggests closely overlapping pocket depth distributions making this parameter inappropriate to predict the gingival biotype in a patient. Still, a comparable distinction in pocket depth was noticed by Olsson et al. (1993). These and our data confirm that shallower pockets may be expected in patients with a thin-scalloped biotype and that deeper pockets coincide with a thick-flat biotype. An explanation for this observation has been earlier described: patients with a quadratic crown form have a thicker periodontium and may respond to gingival inflammation by means of pocket formation. In contrast, individuals with a tapered crown form and comparatively thinner periodontium may be more susceptible to gingival recession (Weisgold 1977, Seibert & Lindhe 1989, Olsson & Lindhe 1991).

In conclusion, the present analysis using a simple and reproducible method for GT assessment confirmed the existence of gingival biotypes. A clear thin gingiva was found in about one third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced 'thin-scalloped biotype' (cluster A1). A clear thick gingiva was found in about two thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced 'thick-flat biotype' (cluster B). The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop (cluster A2).

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Chapter 5

The rationale for using tapered titanium implants with a micro-roughened body and turned collar

Two-piece implants with turned versus micro-textured collars

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ABSTRACT

Implant companies have been promoting two-piece implants with micro-textured collars, as claimed, in the interest of hard tissue preservation and/or soft tissue integration. However, this rationale may not be justified. Based on comparative studies currently available, it is unclear whether micro-roughened implant necks reduce crestal bone loss. A possible effect may be overruled by the establishment of a biologic width or by other factors influencing crestal bone remodeling. In addition, the orientation and attachment of the collagen fibers in the peri-implant mucosa are little different as the surface roughness varies at the level of the implant neck. The clinician should be reserved when using these modified implants since the impact of micro-textured collars on the initiation and progression of peri-implant pathology is currently unknown.

INTRODUCTION

In 1977, the first clinical report on osseointegrated oral implants was published (Brånemark et al. 1977). The original protocol included submerged healing of machined titanium implants. Mainly based on empirical data, uncovering of these implants was postponed until 3 to 6 months after placement. Even though this traditional protocol has been shown to be highly predictable, implant therapy has strongly evolved during the last two decades basically driven by an enlargement of treatment objectives: whereas implant therapy was once one of the treatment options for the functional restoration of edentulous arches, the main goal of contemporary implantology has become the replacement of lost teeth regardless of the type of edentulism. For an implant restoration to be a success it should closely resemble what once existed in nature from a functional as from an esthetic point of view, hereby including the need for preserving or even recreating hard and soft tissues. In addition, patients expect these implant restorations to be finalized within the shortest possible time span.

In order to meet these demands, implant designs and surface topography have changed. Especially a roughened implant surface has shown significant biomechanical advantages over a turned surface.

The biologic advantage of a roughened surface includes an increase of the contact area with blood cells in the so-called 'healing compartment' resulting in the adherence of more platelets (Park & Davies 2000). Concurrently, a roughened surface activates these platelets in releasing cytokines (Park et al. 2001). As a result, osteogenic cells migrate towards the implant surface via the fibrine web and contact osteogenesis is initiated (Davies 2003).

The mechanical advantage of a roughened surface relates to increased bone-to-implant contact (Ericsson et al. 1994). Consequently, two to three times higher torque removal forces for roughened implants can be expected when compared to machined implants (Gotfredsen et al. 1992). Hereby, implant surgery in areas with poor bone quality (Weng et al. 2003) and the use of short (das Neves et al. 2006) and small-diameter implants (Romeo et al. 2006) have become more predictable. In addition, optimization of osseointegration benefits the time gain: ample studies have been published concentrating on the progressive shortening of the load-free healing period for mandibular (Schnitman et al. 1997, Randow et al. 1999) and maxillary multi-unit implant reconstructions (Degidi et al. 2005, Ibanez et al. 2005).

In a series of studies, Wennerberg and co-workers (2003) identified the optimal implant surface characteristics. The most ideal degree of osseointegration as determined by histologic means and torque removal forces was found for implants with an isotropic surface and an irregularity value (s_a) of 1.4 µm (Wennerberg et al. 2003). Currently available roughened implants have s_a values between 0.9 and 2.5 µm (Wennerberg et al. 2003). Interestingly, some machined implants with an anisotropic surface may have a relatively high average height deviation (MKIII, Nobel Biocare™[1]: s_a = 0.7) (Wennerberg et al. 2003).

The optimal surface irregularity characteristics of the implant collar have not yet been described. Still, implant companies have been promoting two-piece implants with micro-textured collars, as claimed, in the interest of hard tissue preservation and/or soft tissue integration. The objective of this manuscript was to critically comment on this trend by

[1] Göteborg, Sweden

interpreting scientific data currently available on the management of hard and soft tissues surrounding two-piece implants with turned and micro-textured collars.

HARD TISSUE PRESERVATION AROUND TWO-PIECE IMPLANTS: IMPACT OF COLLAR SURFACE ROUGHNESS

Factors influencing peri-implant crestal bone remodeling

1. The thickness of the soft tissues when an implant is uncovered.

It has been shown that irrespective of the implant system, design or surgical approach, a biologic width of at least 3 mm will be established once an implant becomes uncovered (Berglundh et al. 1991, Berglundh & Lindhe 1996, Abrahamsson et al. 1996, Hermann et al. 1997, Abrahamsson et al. 1999, Hermann et al. 2000, Hermann et al. 2001a, Wennerberg et al. 2003). Unless this soft tissue thickness is present, peri-implant bone loss will occur to accommodate the necessary soft tissue dimension (Berglundh & Lindhe 1996, Wennerberg et al. 2003). Hereby, the gingival biotype may influence peri-implant hard tissue conditions. Note that around one-piece implants bone remodeling is immediately initiated to establish the biologic width as these fixtures are usually not covered by soft tissues. Since two-piece implants can be placed in a two-stage or one-stage procedure by immediately connecting either a healing cap or a temporary implant-retained restoration, the time point as of which remodelling takes place to establish the biologic width may vary.

2. The position of the microgap or 'implant-abutment interface'.

It is hypothesized that because of microleakage a so-called 'inflammatory cell infiltrate' is formed surrounding the implant-abutment interface, which results in horizontal and vertical bone resorption within at least 1.5 mm (Broggini et al. 2003, Piattelli et al. 2003). This phenomenon could explain the typical 'saucerization' around two-piece implants placed at or below the alveolar crest. Since one-piece implants have no implant-abutment interface less bone remodeling can be expected. In fact, the rough/smooth border determines the level of the crest around one-piece implants (Hermann et al. 1997, Hermann et al. 2000). Note that when a two-piece implant is placed at least 1.5 mm above the level of the crest, the microgap does not affect bone remodeling and the healing process becomes similar to that surrounding a one-piece implant (Hermann et al. 2000).

Interestingly, in contrast to the position of the microgap, its size does not seem to have an impact on crestal bone remodeling (Hermann et al. 2001b, King et al. 2002). However, a tight connection between the components is crucial when maximal hard tissue preservation is persued (Hermann et al. 2001b, King et al. 2002).

3. Macro-structure of the implant-abutment interface.

Apart from the position of the implant-abutment junction, peri-implant bone levels may also be influenced by the macro-structure of the interface (Vela-Nebot et al. 2006). Recently, the concept of 'platform switching™' has been introduced and described as a potential means to preserve peri-implant bone around two-piece implants (Baumgarten et al. 2005, Lazzara & Porter 2006). Basically, an abutment with a smaller diameter than the implant shoulder is connected. It is hypothesized that by 'switching' the diameter of the platform at the level of the implant-abutment interface, the 'inflammatory cell infiltrate', which induces peri-implant bone resorption, is medialized and hereby its distance to the surrounding bone is enlarged. This would explain the preservation of bone at the level of the microgap when small-diameter abutments are connected to implants with wider platforms. Recently, Vela-Nebot and co-workers (2006) have described a significant reduction of bone loss by 1.7 mm for implants with a modified interface in comparison to fixtures with a standard interface. Although 'platform switching™' is linked to the Biomet-3i™[2] Implant System, other systems among which Astra Tech™[3] and the Ankylos™[4] Implant System have been using small diameter abutments on wider implant platforms for many years. Still, the additional value of this concept in the preservation of peri-implant bone needs to be elucidated as it has been poorly documented in comparative studies so far.

4. Implant-to-abutment connection system.

Some studies have emphasized the relevance of the implant-to-abutment connection system in preventing stress-induced bone resorption (Hansson 2000, Hansson 2003). At least from a mechanical point of view, conical implant-to-abutment connections are preferred over flat-to-flat connections as they are superior when subjected to bending tests (Norton 2000). In addition, load is more evenly distributed on the implant surface for the conical connection, whereas stress is concentrated at the most coronal part of the implant collar for the flat-to-flat connection (Hansson 2000, Hansson 2003). Interestingly, these findings were not confirmed by others questioning the impact of the implant-abutment connection system in the management of peri-implant bone (Cehreli et al. 2004).

5. Macro-structure of the implant collar.

Another determining factor in the maintenance of the peri-implant bone may be the macro-structure of the implant collar. Conical collars appear to induce more bone loss in comparison with straight collars (Norton 1998). However, roughening the surface structure of the conical collar seems to enhance bone maintenance (Norton 1998). In addition, implant necks with retention elements such as microthreads seem to be superior over smooth collars in reducing crestal bone loss and in promoting the early biomechanical adaptation against loading (Hansson 1999, Abrahamsson & Berglundh 2006, Shin et al. 2006).

6. Load-free healing time.

Reduced peri-implant bone loss has been reported by reducing the load-free healing time (Engquist et al. 2004, Engquist et al. 2005).

Collar surface roughness: a decisive factor for peri-implant crestal bone remodeling?

Table 5.1 summarizes comparative studies of two-piece implants with a turned (Astra Tech Machined™ or Brånemark Mark II, Nobel Biocare™) versus fully-roughened surface (Astra Tech TiOblast™ or Astra Tech Microthread™) placed at the level of the alveolar crest according to the standard protocol. 8 reports could be retrieved corresponding to 5 studies (Karlsson et al. 1998, Astrand et al. 1999, Puchades-Roman et al. 2000, van Steenberghe D. et al. 2000, Gotfredsen & Karlsson 2001, Engquist et al. 2002, Astrand et al. 2004, Hallman et al. 2005).

[2] Palm Beach, Florida, USA

[3] Mölndal, Sweden

[4] Friadent GmbH, Mannheim, Germany

Table 5.1. Comparative studies of two-piece implants with a turned versus fully-roughened surface

Authors	Study concept	Type of edentulism	Implants: types & numbers	Observation period	Implant survival rate (%)	Crestal bone loss from baseline # (mm)	Crestal bone level in reference to implant shoulder (mm)
Karlsson et al. 1998[40]	Prospective Study	Partial edentulism	Astra Tech Machined: n=64	2 years	95.3	0.26	/
			Astra Tech TiOblast: n=64		***100***	***0.22***	/
Gotfredsen & Karlsson 2001[41]				5 years	95.3	0.21	/
					100	***0.51***	/
Astrand et al. 1999[42]	Prospective Study	Full edentulism	Brånemark Mark II: n=187	1 year	95.7	0.02 (maxilla)	2.12 (maxilla)
						0.31 (mandible)	1.90 (mandible)
			Astra Tech TiOblast: n=184		***99.5 ****	***0.23 (maxilla)***	***1.70 (maxilla)***
						0.31 (mandible)	***1.27 (mandible)***
Engquist et al. 2002[43]				3 years	95.2	0.08 (maxilla)	2.18 (maxilla)
						0.22 (mandible)	1.81 (mandible)
					98.9 *	***0.28 (maxilla)***	***1.75 (maxilla)***
						0.22 (mandible)	***1.18 (mandible)***
Astrand et al. 2004[44]				5 years	94.6	0.10 (maxilla)	2.20 (maxilla)
						0.29 (mandible)	1.88 (mandible)
					98.4	***0.44 (maxilla)***	***1.91 (maxilla)***

						0.13 (mandible)	***1.09 (mandible)***
Puchades-Roman et al. 2000[45]	Cross-sectional study	Partial edentulism: single-tooth replacements	Brånemark Mark II: n=15	2 years	/	/	1.60
			Astra Tech Microthread: n=15		/	/	***0.30 (mesial) **** ***0.60 (distal) ****
van Steenberghe et al. 2000[46]	Prospective study (split-mouth design)	Bilateral partial edentulism	Brånemark Mark II: n=45	2 years	97.7	0.00	2.30
			Astra Tech TiOblast: n=30		***100***	***0.20***	***1.66 ****
Hallman et al. 2005[47§]	Prospective Study	Partial edentulism in the augmented posterior maxilla	Brånemark Mark II: n=84	5 years	87	/	2.30
			Astra Tech TiOblast: n=72		***94.5***	/	***2.40***

Bold & italics: implants with a fully-roughened surface

§ Implants placed in augmented bone

Mean crestal bone loss between baseline and final examination point. Baseline is considered the time of loading (final prosthesis installation)

* Statistically significant intergroup difference (5% level of significance)

Based on these reports, the survival rate of fully-roughened implants seems at least comparable to what was found for fixtures with a turned surface.

When scrutinizing crestal bone loss from baseline, it is clear that for all implants studied, the data are in line with the success criteria proposed by Albrektsson et al (1986), suggesting an annual bone loss of maximum 0.2 mm after the first year of function. Another finding is that none of the studies indicated a significant difference in crestal bone loss from baseline between implants with a turned or fully-roughened surface. This is not surprising knowing baseline corresponded to the time of loading in these reports. At this time point, however, bone remodeling may already have reached a steady state as most of the remodeling process around two-piece implants takes place between fixture installation and connection of the prosthetic components (Hermann et al. 1997, Hermann et al. 2000, Astrand et al. 2004). Logically, if there are disparities in resorption patterns between implants with different surface characteristics, they are likely to occur within this time span. In consequence, recording the crestal bone level at various time points in relation to the implant shoulder may be more relevant when comparing implant surfaces. Based on this parameter, Puchades-Roman et al. (2000) and van Steenberghe et al. (2000) found significantly less bone loss around fully-roughened implants. The group by Astrand and Engquist (1999, 2002 & 2004) described a similar, yet non-significant trend based on a higher number of implants. The impact of collar surface roughness could be a possible explanation for the observed phenomenon as it has been earlier hypothesized that roughened surfaces provide better biomechanical stimulation of the bone surrounding the implant neck than smooth surfaces because the former generate a more heterogenous stress field (Wiskott & Belser 1999). Still, we believe it is premature to conclude that micro-structured implant collars reduce crestal bone loss, at least on the basis of studies that compare two implant systems with different macro- and micro-structures (Brånemark™ implants versus Astra Tech™ implants). Indeed, besides micro-structure at the level of the implant neck, these systems differ in macro-structure of the implant-abutment interface (abutment diameter is smaller than the implant shoulder diameter for Astra Tech implants) and in implant-to-abutment connection system (flat-to-flat connection for Brånemark™ implants versus conical implant-to-abutment connection for Astra Tech™ implants). Since these factors may influence crestal bone levels (Hansson 2000, Hansson 2003, Vela-Nebot et al. 2006, Lazzara & Porter 2006), it is unclear to what extent the results in the studies by Puchades-Roman et al. (2000) and van Steenberghe et al. (2000) are related to the micro-structure of the implant collar. In addition, Puchades-Roman et al. (2000) included Astra Tech™ implants with micro-textured / microthreaded collars. Clearly, the presence of retention elements becomes imperative as they have been associated with reduced crestal bone loss (Hansson 1999, Abrahamsson & Berglundh 2006, Shin et al. 2006). In this regard, the reports by Karlsson et al. (1998) and Gotfredsen & Karlsson (2001) may be more relevant to the topic of this manuscript as only one implant system (Astra Tech™) was used, hereby excluding other influencing factors on crestal bone remodeling. Unfortunately, only marginal bone changes from baseline, i.e. prosthesis installation, were provided. Clearly, more long-term prospective comparative studies using one implant system, monitoring crestal bone changes from fixture installation, are needed to elucidate the impact of collar surface roughness on bone remodeling.

SOFT TISSUE INTEGRATION AROUND TWO-PIECE IMPLANTS: IMPACT OF COLLAR SURFACE ROUGHNESS

It has been shown that the composition of the peri-implant mucosa is hardly affected by the implant system (Abrahamsson et al. 1996, Hermann et al. 2001a). Once an implant becomes uncovered a biologic width is established, which is built up by connective tissue and junctional epithelium (Berglundh et al. 1991, Berglundh & Lindhe 1996, Abrahamsson et al. 1996, Abrahamsson et al. 1999). Around a two-piece implant, the junctional epithelium extends to the implant-abutment interface (or even slightly below that level) and connective tissue borders the implant collar. In contrast to the connective tissue of the healthy periodontium, more collagen fibers are found around implants which mostly run parallel to the titanium surface without attaching to it (Berglundh et al. 1991). Recent reports have indicated that neither the chemical composition nor the surface topography of the implant neck have a significant impact on the orientation of these collagen fibers (Abrahamsson et al. 2001, Comut et al. 2001). Hence, micro-roughened implant collars do not necessarily provide a better seal than smooth collars. Yet, these findings seem to contrast earlier reports (Schroeder et al. 1981, Piattelli et al. 1997). It has to be anticipated, however, even when collagen fibers are more perpendicularly disposed, there is no real functional insertion as found around natural teeth (Capri 2006).

TWO-PIECE IMPLANTS WITH MICRO-TEXTURED COLLARS: POSSIBLE PATHOLOGIC IMPLICATIONS

It has been documented that roughened implant surfaces promote rapid bone apposition and result in more bone-to-implant contact in comparison to smooth surfaces (Gotfredsen et al. 1992, Ericsson et al. 1994). Even though this may be of particular interest in case of bone deficiency or poor bone quality, one should take into account that rough surfaces accumulate plaque intensely once they get exposed to the oral environment (Quirynen et al. 1996). In line with this finding, it has been described that transmucosal implant surfaces with a higher surface roughness/surface free energy facilitate biofilm formation (Teughels et al. 2006). These observations suggest that roughened implants are more prone to develop peri-implant mucositis and peri-implantitis, which is in accordance with the results of a systematic review on the integration and clinical performance of different types of implants (Esposito et al. 2005). In this regard, especially the topography of the implant neck may be critical in the initiation of peri-implant pathology as it borders the oral cavity. Since the impact of micro-textured implant collars on the initiation and progression of peri-implant pathology has not yet been documented, the clinician should be reserved when using these modified implants especially in high-risk patients such as those with a history of aggressive periodontitis. After all, peri-implantitis may be more difficult to treat than periodontitis if only because of the presence of threads along the implant surface compromising proper mechanical debridement. Hitherto, there has not been made any consensus on how to treat peri-implantitis. However, this disease may become the problem of the future as its incidence is increasing simply because more and more implants are used in the oral rehabilitation of patients.

CONCLUSIONS

Peri-implant bone remodeling is mainly driven by the establishment of the biologic width. Other factors have been described showing a possible impact on crestal bone levels. At least based on long-term comparative studies currently available, it is unclear whether micro-roughened implant necks reduce crestal bone loss. More long-term prospective comparative studies using one implant system, monitoring crestal bone changes from fixture installation, are needed to elucidate the impact of collar surface roughness on bone remodeling.

The orientation and attachment of the collagen fibers in the peri-implant mucosa are little different as the implant collar surface roughness varies. By consequence, micro-roughened implant collars do not provide an obvious advantage over smooth collars. The clinician should be reserved when using these modified implants as the long-term impact of micro-textured collars on the initiation and progression of peri-implant pathology is currently unknown.

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Chapter 6

Short-term clinical outcome of immediate single-tooth implants in the anterior maxilla

Immediate single-tooth implants in the anterior maxilla: a one-year case cohort study on hard and soft tissue response

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ABSTRACT

Objectives: The objective of the present study was to assess implant survival rate, hard and soft tissue response and esthetic outcome one year after immediate placement and provisionalization of single-tooth implants in the premaxilla. All patients underwent the same strategy, that is mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material between the implant and the socket wall and the connection of a screw-retained provisional restoration.

Materials and methods: Thirty consecutive patients were treated for single-tooth replacement in the esthetic zone by means of immediate implant placement and provisionalization. Reasons for tooth loss included caries, periodontitis or trauma. At 6 months provisional crowns were replaced by the permanent ones. Clinical and radiographic evaluation was completed at 1, 3, 6, and 12 months to assess implant survival and complications, hard and soft tissue parameters and patient's esthetic satisfaction.

Results: One implant had failed at one month of follow-up resulting in an implant survival rate of 97 %. Radiographic examination yielded 0.98 mm mesial, respectively 0.78 mm distal bone loss. Midfacial soft tissue recession and mesial/distal papilla shrinkage accounted for 0.53 mm, 0.41 mm and 0.31 mm, respectively. Patient's esthetic satisfaction was 93 %.

Conclusions: The preliminary results suggest that the proposed strategy can be considered a valuable treatment option in well-selected patients.

INTRODUCTION

The prosthetic rehabilitation of a single maxillary anterior tooth with an implant supported fixed prosthesis is an accepted concept. The original Brånemark protocol suggested 3 months of soft and hard tissue healing following tooth removal and an additional 3 to 6 month load-free osseointegration period (Albrektsson et al. 1981, Brånemark 1983). This leads to many months of waiting with an uncomfortable removable partial denture and several surgical interventions. Based on aforementioned concerns, patients occasionally prefer a traditional, sometimes destructive, bridge construction.

In the last decade, Implant Dentistry has strongly evolved: the original protocol has been modified by several investigators to include one-stage surgery (Becker et al. 1997), immediate postextraction implant placement (Lazzara 1989, Werbitt & Goldberg 1992, Polizzi et al. 2000) and immediate provisionalization (Gomes et al. 1998, Ericsson et al. 2000). Studies have been published in which these three approaches are combined (De Rouck et al. 2008). Most of these reports focused, however, on implant survival and preservation of hard tissues with much less attention to the soft tissue architecture. Needless to say, the esthetic success of a restoration is determined by the harmony of the hard and soft tissues (Touati 1995, Grunder et al. 1996).

In this study single-tooth replacement was performed by means of mucoperiosteal flap elevation, immediate post-extraction implant placement, insertion of a grafting material and the connection of a screw-retained provisional restoration. The rationale of this treatment concept and its outcome on hard and soft tissues following a one-year study period are discussed in this paper.

MATERIALS AND METHODS

Patient selection

This study included 30 consecutively treated cases in 30 different patients in the Dental Clinic of the Free University in Brussels (VUB). Patients were selected during a screening visit on the basis of inclusion and exclusion criteria.

Inclusion criteria were as follows:

1. At least 18 years old.
2. Good oral hygiene.
3. Presence of a single failing tooth in the anterior maxilla (15-25) with both neighboring teeth present.
4. Ideal soft tissue contour at the facial aspect of the hopeless tooth in perfect harmony with the surrounding teeth.
5. Normal to thick-flat gingival biotype.
6. Adequate bone height apical to the alveolus of the failing tooth (≥ 5 mm) to ensure primary implant stability of at least 35 Ncm.

Exclusion criteria were as follows:

1. Systemic diseases.
2. Smoking (≥ 10 cigarettes a day).
3. Bruxism, lack of posterior occlusion.

4. Non-treated periodontal diseases.
5. Presence of active infection (pus, fistula) around the hopeless tooth.
6. Loss of the labial crest after extraction of the failing tooth.

Surgical procedure

Following screening, comprehensive clinical and radiographic examination was performed by two experienced clinicians (JC/TDR) and impressions were taken of both jaws for model analysis. Thereupon, a treatment plan was proposed. All patients consented to the planned treatment strategy, which was reviewed and approved by the ethical board.

One hour pre-operatively, patients were advised to start antibiotic and analgesic therapy (Amoxicillin 500 mg and Ibuprofen 600 mg). Oral disinfection was performed using a 0.2 % chlorhexidine digluconate mouthwash (Corsodyl, GlaxoSmithKline, Genval, Belgium).

Teeth scheduled for immediate replacement were systematically removed following minimal mucoperiostal flap elevation (fig.6.1 a & b). Periotomes were used to extract as atraumatic as possible. Immediate implant placement (Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden) was performed if the labial crest was intact. Special attention was paid to a correct selection and three-dimensional positioning of the implant. In the orofacial dimension, the implant shoulder was positioned palatal to the point of emergence at adjacent teeth. In the mesiodistal dimension, a distance of the implant shoulder to the neighboring teeth of about 2 mm was pursued. In the apicocoronal dimension, the implant shoulder was 1 mm subcrestally positioned or about 4 mm below the outline of the peri-implant mucosa (fig.6.1.b). In order to obtain primary implant stability of at least 35 Ncm, which was considered a prerequisite for immediate provisionalization in this study, surgical sites were frequently under-prepared. Following confirmation of the primary stability using a Torque Controller (Nobel Biocare, Göteborg, Sweden), implant impression was made (fig.6.1.c). The final implant position was recorded using radio-opaque and sterile vinylpolysiloxane material (Elite implant® medium, Zhermack, Badia Polesine, Italy). After ensuring that no impression material had remained at the surgical site, a cover screw was attached to the implant and grafting material (Bio-Oss® 0.25 mm – 1 mm, Geistlich Biomaterials, Wolhusen, Switzerland) soaked in blood were inserted to fill the void between the implant and the alveolus. Particles were gently condensed and applied to the level of the implant shoulder. All voids were grafted irrespective of their width. Finally, the cover screw was replaced by an appropriate healing abutment and the wound was closed by means of single sutures (Vicryl® 5/0, Johnson & Johnson, St-Stevens-Woluwe, Belgium). Postoperative instructions included avoidance of the surgical site while brushing and eating, the use of a 0.2 % chlorhexidine mouthwash 2 times a day for 2 weeks and antibiotic therapy for 5 days (Amoxicillin 500 mg 3 times a day). If necessary, analgesic therapy (Ibuprofen 600 mg maximum 3 times a day) was continued. All surgical procedures were performed by one and the same surgeon (JC).

Fabrication of the provisional restoration

Using the implant impression taken at the time of surgery, an individualized screw-retained provisional crown was fabricated in the dental laboratory. In brief, an engaging titanium temporary abutment (Nobel Biocare, Göteborg, Sweden) served as a carrier for an appropriate hollowed denture tooth (fig.6.1.d). Selection of the latter was principally driven by design and color of the failing tooth. Autopolymerizing acrylic resin (Palavit® 55 VS, Heraeus Kulzer, Hanau, Germany) was used to bond the temporary abutment and the denture tooth and for designing the cervical portion of the restoration. As a model of the opponent jaw was available, the provisional restoration was adjusted to clear centric and eccentric contacts prior to polishing procedures. All temporary crowns were fabricated by one and the same prosthodontist (TDR).

Connection of the provisional and permanent restoration

Approximately 3 hours following implant installation, the healing abutment was removed by the prosthodontist and the provisional restoration was tightened at 15 Ncm onto the fixture. In order to avoid contamination, all restorations had been provided with 1 % chlorhexidine digluconate gel at the abutment screw level. The clinician made sure that the provisional restoration was cleared of all contact in centric occlusion and during eccentric movements in order to avoid full functional loading of the implant during healing. Avoidance of the site while eating during an 8 week period was recommended. Fig.1.e shows an example of a provisional restoration after 3 months of follow-up.

After 6 months the provisional restoration was replaced by a permanent cemented restoration. Therefore, standard implant impression was made using a polyether impression material (Impregum Penta®, 3M ESPE, Seefeld, Germany) and an open tray impression coping (Nobel Biocare, Göteborg, Sweden). Special attention was given to an accurate replication of the soft tissue architecture. A standard esthetic titanium abutment (Esthetic Abutment, Nobel Biocare, Göteborg, Sweden) was used to connect the permanent metal-ceramic restoration. Cementation was performed using temporary cement (Temp-Bond® NE, Kerr, Scafati, Italy). In fig. 1f an example of a permanent restoration after a follow-up period of 1 year is shown.

All prosthetic procedures were conducted by one and the same prosthodontist (TDR) and all permanent restorations were fabricated in one and the same dental laboratory (Dental Art, Zottegem, Belgium).

Figure 6.1.a Fracture of tooth 12 near the level of the alveolar crest.

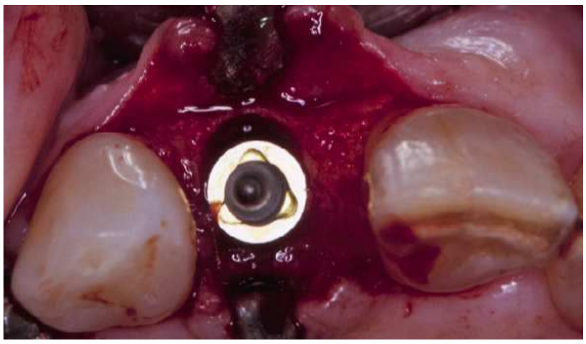

Figure 6.1.b Minimal mucoperiosteal flap reflection, tooth extraction and restoration-driven implant placement (Nobelreplace tapered TiUnite® diameter 4.3 mm - length 16 mm).

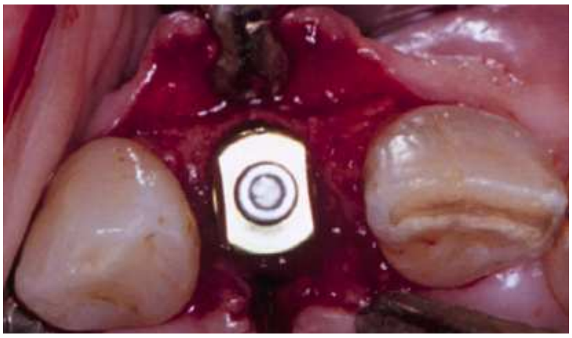

Figure 6.1.c Connection of a standard impression coping for the open tray impression technique.

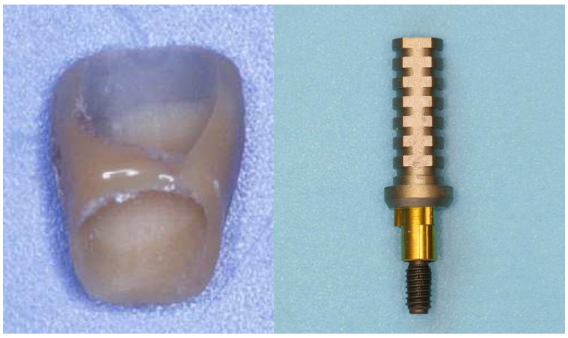

Figure 6.1.d Autopolymerizing acrylic resin is used to bond an appropriate hollowed denture tooth (left) and a temporary titanium abutment (right)

Figure 6.1.e Labial view of the provisional screw-retained restoration after 3 months of follow-up.

Figure 6.1.f Labial view of the permanent cemented restoration after 1 year. Note some additional fill of the mesial interdental space between the 3-month and 12-month follow-up visit.

Implant survival and complications

At each re-assessment, namely after 1, 3, 6 and 12 months of follow-up, implant survival and complications were evaluated. The criteria for success of osseointegration according to Smith & Zarb (1989) were adopted. These criteria essentially include major bone loss, radiolucency, mobility, pain, discomfort and/or neurosensory changes. All biologic and prosthodontic complications were recorded during the study period.

Hard tissue parameters

Immediately following connection of the provisional restoration and after 3, 6 and 12 months a peri-apical radiograph was taken using the long-cone paralleling technique and an X-ray holder (XCP Bite Block, Dentsply Rinn, Elgin, USA). An occlusal jig (Futar® D Fast, Kettenbach Dental, Eschenburg, Germany) was used to standardize the angulation and position of the film in relation to the implant and X-ray beam. All radiographs were scanned (300dpi) and digitized (SprintScan 35 Plus, Polaroid, Cambridge, USA). Changes in marginal bone levels at the mesial and distal aspect of the implant were based on the exact distance between 3 implant threads as provided by the implant manufacturer (Nobel Biocare, Göteborg, Sweden). The appropriate software (Vixwin 2000 v1.11, Dentsply Gendex, Lake

Zurich, Swiss) was used to calculate bone level changes over time. All radiographs were analyzed by two clinicians (JC/TDR).

Soft tissue parameters

At 1, 3, 6 and 12 months of follow-up, the *clinical condition* of the implant-restoration was recorded by means of the following parameters:

1. *Plaque score*. A dichotomous score was given (0 = no visible plaque at the soft tissue margin; 1 = visible plaque at the soft tissue margin) at 4 sites per implant (mesial, midfacial, distal, palatal).
2. *Probing depth* was measured to the nearest 0.5 mm at 4 sites per implant (mesial, midfacial, distal, palatal) using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, USA).
3. *Bleeding on probing*. A dichotomous score was given (0 = no bleeding; 1 = bleeding) at 4 sites per implant (mesial, midfacial, distal, palatal).

At each of the re-assessments, oral hygiene was reinforced.

Prior to tooth removal and at 1, 3, 6 and 12 months of follow-up, *soft tissue dimensions* were measured as follows:

1. *Papilla levels* were recorded by means of an acrylic stent provided with direction grooves by two clinicians (fig.6.2). A papilla level (mesial papilla level - distal papilla level) is defined as the distance between the top of the groove and the top of the papilla measured to the nearest 0.5 mm using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, USA).
2. *Midfacial mucosa level*. The level of the peri-implant mucosa at the midfacial aspect of the tooth/restoration was measured using the same acrylic stent provided with a central direction groove by two clinicians. The midfacial level is defined as the distance between the top of the groove and the first contact with the peri-implant mucosa measured to the nearest 0.5 mm using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, USA).

Figure 6.2 Acrylic stent with 3 direction grooves to determine the outline of the soft tissues at the mesial, distal and midfacial aspect of the restoration.

Patient's esthetic satisfaction

At the end of the study period, patients were asked to express their satisfaction in reference to the esthetic outcome on the basis of a 10 cm visual analogue scale labeled with 'not at all satisfied' at the zero point and 'completely satisfied' at the right end point. A staff member (IW), who was not involved in the treatment, was charged with presenting the following question: 'How would you rate your satisfaction with respect to the esthetic outcome of your treatment?'

Statistical analysis

Data analysis was performed using the patient as the experimental unit. For all parameters mean values per subject and per visit were calculated, if applicable. The changes over time of these variables were examined by means of repeated measures one-way analysis of variance (ANOVA). The level of significance was set at 5 %.

RESULTS

From the 32 patients that had been scheduled from May 2005 to June 2006, 30 (14 men, 16 women; mean age of 54 with a range from 24 - 76) were actually treated for single-tooth replacement in the esthetic zone by means of immediate implant placement and provisionalization. Two patients had to be excluded during surgery as loss of the labial crest occurred after extraction of the failing tooth. Table 6.1 shows tooth types and reasons for tooth loss: more than half were incisors and the most prevalent reason for failure was tooth fracture. 30 screw-type tapered implants with a micro-roughened body and machined collar (Nobelreplace tapered TiUnite®: diameter 4.3 mm – length 10 mm: 2 implants; diameter 4.3 mm – length 13 mm: 8 implants; diameter 4.3 mm – length 16 mm: 14 implants; diameter 5 mm – length 13 mm: 2 implants; diameter 5 mm – length 16 mm: 4 implants) were inserted. The bone gap between the alveolus and the implant platform that was filled with Bio-Oss® particles had an average orofacial dimension of 1.38 mm (range 0 - 4 mm) at the midfacial aspect of the implant. Table 6.2 shows the distribution of the gap width sorted per tooth type.

During the 12-month observation period, one patient was lost to follow-up after 3 months.

Table 6.1. Tooth types and reasons for failure

Tooth types	Reasons for failure				
	Fracture	Caries/ Endodontic	Periodontal	Root resorption	TOTAL
Incisors	8	4	5	2	19
Canines	0	1	0	1	2
Premolars	2	4	2	1	9
TOTAL	10	9	7	4	30

Table 6.2. Width of the gap between implant and bony wall according to the extracted tooth type

Tooth types	0- 1 mm	1.1- 2 mm	2.1- 3 mm	3.1- 4 mm	TOTAL
Incisors	10	9	0	0	19
Canines	1	1	0	0	2
Premolars	3	3	1	2	9
TOTAL	14	13	1	2	30

Implant survival and complications

At one month follow-up, one of the implants had failed (tooth location 21; diameter 5 mm - length 16 mm) as pain, discomfort and implant mobility occurred. The reason for this early loss was unclear. Besides this one early failure, all implants remained well-integrated based on the success criteria for osseointegration proposed by Smith & Zarb (1989) resulting in a 97 % cumulative implant survival rate after one year of function. In reference to complications within this observation period, one permanent crown had lost retention at 8 months of follow-up and was re-cemented.

Hard tissue parameters

Table 6.3 shows the changes in mesial and distal bone levels at 3, 6 and 12 months of follow-up in relation to the time point of connecting the provisional restoration. The largest amount of bone loss was observed in the first 3 months: 0.58 mm mesially and 0.47 mm distally. Thereafter, diminished loss was observed. After one year of function radiographic examination yielded 0.98 mm mesial bone loss, respectively 0.78 mm distal bone loss.

Table 6.3. Changes in marginal bone levels in relation to the time point of connecting the provisional restoration

Location	Month 3	Month 6	Month 12
Mesial bone level (mm)	0.58 ± 0.41	0.85 ± 0.52	0.98 ± 0.50
Distal bone level (mm)	0.47 ± 0.65	0.66 ± 0.70	0.78 ± 0.55

Mean ± SD

Soft tissue parameters

In table 6.4 the *clinical conditions* of the implant restorations are shown. Throughout the study period, plaque scores remained low (< 20 %), In fact 82 % of the subjects demonstrated plaque scores of maximum 25 %. About half of the sites exhibited bleeding on probing. A trend towards a reduction in probing depth from 3.90 mm to 3.46 mm was found. There were no significant differences in any of the parameters over time.

Table 6.5 indicates high agreement among both clinicians for recording *soft tissue dimensions*. Identical scoring was found in more than 80 %.

Table 6.6 depicts the dimensional changes of the soft tissue outline around the implant restorations in relation to the status prior to tooth extraction. The largest reductions in papilla height were found at 3 months of follow-up pointing to a mean loss of 0.64 mm (p<0.001) for mesial papillae and 0.50 mm (p=0.005) for distal papillae. Although there were no significant differences in papilla height among the different time points, a trend towards some regain following 3 months of healing was apparent: at one-year of follow-up the average papilla loss was 0.41 mm (p=0.035) at the mesial aspect of the restoration, respectively 0.31 mm (p>0.05) at its distal aspect. In fig. 1e & f the phenomenon is illustrated.

The largest alterations in the midfacial level of the peri-implant mucosa occurred during the first month of healing, pointing to a mean loss of 0.43 mm (p=0.002). At the one-year follow-up visit, the midfacial soft tissue recession was on average 0.53 mm (p=0.011). There were no significant changes in midfacial soft tissue levels among the different time intervals.

Table 6.4. Clinical conditions of implant restorations at different time intervals

Parameter	Month 1	Month 3	Month 6	Month 12
Plaque score (%)	17 ± 22	19 ± 21	18 ± 23	17 ± 18
Probing depth (mm)	3.90 ± 0.83	3.76 ± 0.67	3.64 ± 0.76	3.46 ± 0.69
Bleeding on probing (%)	54 ± 30	49 ± 19	46 ± 23	41 ± 16

Mean ± SD

Table 6.5. Inter-examiner reproducibility of soft tissue dimensions

Parameter	Paired samples *t*-test	Pearson's correlation coefficient	Identical scoring (%)
Papilla levels (mm)	NS	0. 994 (p≤0.001)	81
Midfacial mucosa level (mm)	NS	0.995 (p≤0.001)	86

NS Non-significant

Table 6.6. Changes in soft tissue dimensions in relation to the pre-operative status

Parameter	Month 1	Month 3	Month 6	Month 12
Mesial papilla level (mm)	- 0.50 ± 0.73 *	- 0.64 ± 0.76 *	- 0.50 ± 0.75 *	- 0.41 ± 0.71 §
Distal papilla level (mm)	- 0.33 ± 0.83 §	- 0.50 ± 0.78 *	- 0.41 ± 0.85 §	- 0.31 ± 0.83
Midfacial mucosa level (mm)	- 0.43 ± 0.68 *	- 0.48 ± 0.80 §	- 0.54 ± 0.77 *	- 0.53 ± 0.76 §

Mean ± SD

§ Significant soft tissue loss in comparison to the pre-operative status: $0.005 < p \leq 0.05$

* Highly-significant soft tissue loss in comparison to the pre-operative status: $p \leq 0.005$

Patient's esthetic satisfaction

Patient's esthetic satisfaction, as determined by a visual analogue scale, indicated a mean score of 93 % with a range from 82 % to 100 %.

DISCUSSION

The study involved a method for immediate replacement of a hopeless tooth with an implant-supported fixed prosthesis. For the patient, this appears an inviting strategy: it is a one stage procedure and eliminates the need for a removable partial denture in the early stages of healing. Hereby, the patient benefits from immediate esthetics and comfort. From a clinical point of view, the procedure has also its advantages. These are mainly related to time gain as postextraction healing and osseointegration coincide.

Based on the short-term results of the present study, immediate single-tooth implants in the anterior maxilla may be considered a successful treatment strategy with a cumulative implant survival rate of 97 % after one year of function. This result is comparable to other short-term studies using the same protocol (≥ 94 %) (Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003, Kan et al. 2003a, Cornelini et al. 2005, Barone et al. 2006). Studies with longer observation periods yielded survival rates of ≥ 93 % (Groisman et al. 2003, Norton 2004, Tsirlis 2005, Degidi et al. 2006, Ferrara et al. 2006). Interestingly, these survival rates are in line with data published for implants inserted according to the standard protocol (≥ 93 %) (Noack et al. 1999, Goodacre et al. 1999, Krennmair et al. 2002, Romeo et al. 2002, Levin et al. 2006). Hence, the time span from extraction to implant placement does not seem to be the pivotal factor in attaining osseointegration. In contrast, the macro- and microstructure of the implant may be more relevant. In this study, screw-type tapered implants with a micro-roughened body and machined collar were used. This selection seemed evident as more bone-to-implant contact is found around screw-type implants in comparison to cylindrical implants (Vandamme et al. 2007) and high primary stability can be easily achieved with a tapered implant design (O'Sullivan et al. 2004). In addition, micro-roughened implants have shown significant biomechanical advantages over machined implants: as a result of contact osteogenesis and increased bone-to-implant contact, the former benefit from rapid bone apposition and superior anchorage (Cosyn et al. 2007). Finally, we used implants with a standard machined collar in this study as the additional value of a micro-textured collar is currently unclear (Cosyn et al. 2007). Besides these geometrical implant aspects, osseointegration was further optimized as follows: first, primary implant stability of at least 35 Ncm was pursued and considered a prerequisite for immediate provisionalization. This seemed appropriate since the study of Ottoni and colleagues (2005) revealed a correlation between placement torque and survival of single-tooth implants: 9 out of 10 failing implants were placed with an insertion torque of only 20 Ncm. Appropriate initial insertion torque was advocated by the authors to proceed with early loading (Ottoni et al. 2005). Second, provisional restorations were cleared of all contacts to avoid micromovements, which are sufficient to jeopardize the osseointegration process (Brunski 1993, Brunski et al. 2000). Interestingly, the need for these precautions has recently been questioned by Lindeboom and co-workers (2006) as they found no significant differences in any parameter between immediately loaded and immediately non-loaded provisionalized implants.

Radiographic examination one year after implant placement revealed mean bone loss of 0.98 mm mesially and 0.78 mm distally, which is in agreement with other studies on the current concept (Lorenzoni et al. 2003, Tsirlis 2005). These data are little different from the peri-implant bone changes following the conventional 2-stage procedure in healed sites (Adell et al. 1986, Naert et al. 2002). These findings contribute to the current theory that crestal bone changes are dependent on the location of the microgap irrespective of submerged or non-submerged implant placement (Hermann et al. 2000, Cosyn et al. 2007). In contrast 3 studies on immediate implantation and provisionalization presented limited bone loss pointing to less than 0.50 mm after one year of function (Kan et al. 2003a, Norton 2004, Cornelini et al. 2005). Kan and colleagues (2003a) even observed several implants with bone gain; a phenomenon that was not observed in the present study. This could be explained by a difference in surgical technique.

In spite of the fact that plaque levels remained low throughout the study (< 20 %), nearly half of the sites bled upon probing. This is, however, not an uncommon feature around implants (Chang et al. 1999, Lorenzoni et al. 1999, Roos-Jansaker et al. 2006, Ozkan et al. 2007) as a result of an 'inflammatory cell infiltrate' possibly induced by microleakage at the implant-abutment interface (Broggini et al. 2003, Piattelli et al. 2003) and the subgingival position of a restoration border (Jemt & Pettersson 1993). A relatively high mean probing depth of about 3.5 mm after one year of function was found in this study, which can be considered a normal phenomenon around two-piece implants as described by others (Lekholm et al. 1986, Apse et al. 1991, Proussaefs et al. 2002). An interesting observation was the decreasing trend in probing depth between one month of follow-up (3.90 mm) and study termination (3.46 mm). Similar pocket shrinkage was reported by Proussaefs et al. (2002) from 3.6 mm at 3 months to 3.2 mm at 12 months of follow-up and earlier literature (Apse et al. 1991).

Even though ample reports have been published on immediate implant insertion and provisionalization for replacing maxillary anterior teeth, few have documented esthetic treatment outcome (De Rouck et al. 2007). Hence, one of the objectives of this prospective study was to monitor changes in soft tissue dimensions. Usually a reference line connecting the midfacial gingival level of the two teeth adjacent to the implant restoration is used for this purpose (Chang et al. 1999, Kan et al. 2003a, Cornelini et al. 2005). As midfacial gingival levels may be liable to variation especially when mucoperiosteal flaps are reflected, an acrylic stent with fixed reference points was used in this study. This method proved highly reproducible.

In the present investigation, significant reductions in papilla height were found reaching a maximum of 0.64 mm ($p<0.001$) on average for mesial papillae, respectively 0.50 mm ($p=0.005$) for distal papillae at 3 months of follow-up. Soft tissue swelling may have limited papilla loss in the early stages of healing explaining less discrepancy in relation to the pre-operative status at one month of follow-up. Interestingly, our 3-month data on papilla loss seem considerably higher in comparison to what has been earlier described by Kan and co-workers (2003a). They reported only 0.33 mm mean loss for mesial papillae, respectively 0.25 mm for distal papillae at 3 months following single-tooth replacement in the incisor-cuspid maxillary region by means of immediate implant insertion and provisionalization. This disparity can be explained by the flapless surgical approach in their study resulting in less tissue trauma. However, as the present study and the report by Kan et al. (2003a) indicate comparable levels of papilla loss after one year of function, pointing to approximately 0.5 mm for mesial papillae and 0.3 mm for distal papillae, a possible impact of the surgical technique seems negligible in the longer run. In this regard, it has been well-documented that the presence of a papilla adjacent to a single-tooth implant restoration is principally driven by the level of the alveolar bone on the neighboring tooth (Choquet et al. 2001, Kan et al. 2003b). An interesting observation in our study is the increase in papilla height between the 3-month and one-year visit. Although this was not statistically consolidated by our data, the fact that distal papilla levels were not significantly different from pre-operative levels at the one-year re-assessment is indicative of the phenomenon. This observation seems in line with earlier reports demonstrating an increase in papillary soft tissue volume during the first year of function of single-tooth implant restorations (Chang et al. 1999, Grunder 2000, Cardaropoli et al. 2006).

In this study, significant midfacial soft tissue recession of 0.53 mm in the first year of function was found, which is in agreement with a report by Kan et al. (2003a) indicating 0.55 mm following a similar strategy. Cornelini and associates (2005) described 0.75 mm midfacial soft tissue loss within the same time frame. Other studies have been published on soft tissue topography following single-tooth implant placement in healed sites demonstrating comparable levels of midfacial recession in the first year of function pointing to 0.6 mm (Grunder 2000, Cardaropoli et al. 2006). By on average 3 years of follow-up, midfacial soft tissue loss of about 1 mm has been described for conventional single-tooth implant restorations (Chang et al. 1999). These data seem little different for multiple-unit implant reconstructions (Bengazi et al. 1996, Small & Tarnow 2000). In addition, long-term studies have demonstrated ongoing soft tissue shrinkage up to 1.7 mm, at least in fully-edentulous patients (Adell et al. 1986, Apse et al. 1991). These findings indicate that remodeling is an inevitable and continuous event, making long-term soft tissue monitoring a necessity. At least in the first year of function, our data demonstrate limited loss at the mid-facial aspect, which may be explained as follows: first, patients with a thin-scalloped biotype were excluded in this study. As the risk for esthetic complications is considerably high in these subjects, hard tissue conditioning and/or periodontal plastic surgery are often necessary. These procedures are delicate and require a staged approach. Second, Bio-Oss particles were systematically enclosed between the implant and the socket wall. Even though resorption of the alveolar ridge inevitably occurs following tooth extraction (Schropp et al. 2003, Araujo & Lindhe 2005), it has been shown that significantly more buccal bone can be preserved when the extraction socket is filled with a grafting material exhibiting a low substitution rate such as Bio-Oss (Nevins et al. 2006). As the immediate insertion of an implant has no impact whatsoever on the dimensional changes of the extraction socket

(Botticelli et al. 2004, Araujo et al. 2005), it is conceivable that this bone substitute induces an analogue effect if incorporated between an implant and the socket wall. Evidently, this issue should be investigated in controlled clinical studies. Because of the promising properties of Bio-Oss in this field and because this grafting material does not seem to interfere with osseointegration (Polyzois et al. 2007), we choose to apply it at all times in this study even though the necessity of this procedure in small bone gaps can be considered a matter of debate. Finally, screw-retained instead of cemented provisional restorations were used in this study. This may be the reason no complications were reported during the provisional stage. In contrast, fistulae have been described when using cemented provisional restorations (Kan et al. 2003a).

A flapless surgical technique for anterior implant placement has been earlier advocated for optimal esthetic results (Kan et al. 2000). An advantage of a flapless approach in immediate implant cases is the preservation of blood supply of the buccal socket wall. Still, the clinical relevance of this argument is not well-understood. Moreover, our results after one year of function on soft tissue topography at the midfacial as papilla level seem by no means inferior to those previously published on flapless implant surgery (Kan et al. 2003a). High patient's esthetic satisfaction may reinforce these results. Consequently, raising a flap or not does not seem to be the pivotal factor in achieving esthetic results. The rationale for reflecting minimal mucoperiosteal flaps in this study was threefold: first, it facilitates tooth removal, which can be quite delicate especially when the tooth is fractured or in case of root resorption. Note that these were the reasons for tooth loss in nearly half of our cases. Second, a flap allows the clinician to properly inspect the buccal socket wall for fenestrations and/or dehiscencies. Third, flapless surgery increases the risk of perforation making it a risky procedure when implant placement is not computer-navigated. Other precautions for flapless implant surgery in the esthetic region have been recently described (Oh et al. 2007).

On the basis of the preliminary results of this study, single-tooth replacement by means of mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material and the connection of a screw-retained provisional restoration can be considered a valuable treatment option. The presented protocol offers many advantages as well for the patient as for the clinician. However, careful patient selection and treatment planning seem of critical importance in achieving predictable treatment outcome. Evidently, further research is needed to monitor hard and soft tissue changes on a long term basis.

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Chapter 7

The impact of the restorative procedure on the esthetic outcome of immediate single-tooth implants in the anterior maxilla

Instant provisionalization of immediate single-tooth implants is essential to optimize esthetic treatment outcome

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ABSTRACT

Objectives: The immediate single-tooth implant has become a viable treatment option. However, the impact of the restorative procedure on esthetics is currently unclear. The goal of this study was to compare the soft tissue outline at immediate implants following two restorative protocols: immediate connection of a temporary crown or submerged healing during which a removable partial denture is used.

Material and methods: A one-year single-blind randomized clinical study was performed in 49 patients. 24 patients were assigned to the immediate restoration group and 25 to the delayed restoration group. Clinical and radiographic evaluations of soft and hard tissues were carried out after 3, 6 and 12 months.

Results: Implant survival, bone remodeling, probing depth and bleeding tendency were not influenced by the restorative protocol. Delayed restoration resulted in initial papilla loss taking up to one year to attain comparable height as for immediate restoration. Midfacial recession was systematically 2.5 to 3 times higher following delayed restoration pointing to a 0.75 mm additional loss in comparison to immediate restoration after one year.

Conclusions: If the primary implant stability permits it, immediate single-tooth implants should be instantly provisionalized in the interest of optimal midfacial esthetics.

INTRODUCTION

In the last decade, implant dentistry has strongly evolved including one-stage surgery (Becker et al. 1997), immediate post-extraction implant placement (Lazzara 1989; Werbitt & Goldberg 1992; Polizzi et al. 2000) and immediate (occlusal / non-occlusal) loading (Gomes et al. 1998; Ericsson et al. 2000; Lindeboom et al. 2006; Hall et al. 2007). A review on single-tooth replacements combining these approaches has been published (De Rouck et al. 2008a). Immediate tooth replacement seems an inviting strategy for the patient as he/she benefits from immediate esthetics and comfort. Also from a clinical point of view, the procedure has its advantages, which are mainly related to time gain as post-extraction healing and osseointegration coincide.

A limited number of case-cohort studies on esthetic treatment outcome of immediately restored immediate single-tooth implants have been recently published with promising results (Kan et al. 2003; Cornelini et al. 2005; De Rouck et al. 2008b). In addition, the positive impact of applying a grafting material between the socket wall and the implant on buccal bone preservation and esthetics has been documented (Cornelini et al. 2004, Chen et al. 2007). Still, the influence of variation in the restorative procedure on esthetics of immediate single-tooth implants is currently unclear. This may be relevant as implants placed into extraction sockets cannot always be immediately restored. Especially when primary implant stability appears insufficient the surgeon is forced to alter the treatment plan in favor of conventional submerged healing.

The objective was to evaluate the influence of the restorative protocol (immediate versus delayed restoration) on the esthetic outcome of immediate single-tooth implants over a one-year period by means of a randomized clinical trial (RCT). Tooth-related factors such as tooth dimensions, form and color contribute to esthetics as well as soft tissue-related factors including interdental and midfacial soft tissue dimensions. In this report, only soft tissue related factors were considered in the appraisal of esthetics.

MATERIALS AND METHODS

Patient selection

This study included patients treated for single-tooth replacement in the Dental Clinic of the Free University in Brussels (VUB) based on the following inclusion criteria:

1. At least 18 years old.
2. Good oral hygiene.
3. Presence of a single failing tooth in the anterior maxilla (15-25) with both neighboring teeth present.
4. Ideal soft tissue contour at the facial aspect of the hopeless tooth in perfect harmony with the surrounding teeth.
5. Normal to thick-flat gingival biotype characterized by relatively short and wide teeth, low contact points and short papillae.
6. Adequate bone height apical to the alveolus of the failing tooth (≥ 5 mm) to ensure primary implant stability of at least 35 Ncm.

Exclusion criteria were as follows:

1. Systemic diseases.
2. Smoking (≥ 10 cigarettes a day).
3. Bruxism, lack of posterior occlusion.
4. Non-treated periodontal diseases.
5. Presence of active infection (pus, fistula) around the hopeless tooth.
6. Loss of the labial crest after extraction of the failing tooth.

Study groups

After screening for recruitment, impressions were made to fabricate an acrylic stent for recording purposes (see below). Thereupon, patients were randomly allocated to the 'immediate restoration group' (IRG) or the 'delayed restoration group' (DRG) (26 patients per group). This was done by means of a computer-generated randomization scheme. All patients gave informed consent. The study protocol was approved by the Ethical Committee of the University Hospital in Brussels.

Patients in the IRG were scheduled for surgery and immediate tooth replacement. Surgery included minimal mucoperiosteal flap elevation, tooth extraction, implant placement (Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden) and insertion of a grafting material (Bio-Oss®, Geistlich Biomaterials, Mediplus, Rixensart, Belgium: 0.25 – 1 mm) between the socket wall and the implant. At the time of surgery, a standard implant impression was made to fabricate a screw-retained provisional crown. Temporary restorations were seated within a few hours post-op and adjusted to clear centric and eccentric contacts. Clinical and radiographic evaluations were carried out at 3, 6 and 12 months. At 6 months, provisional crowns were replaced by permanent metal-ceramic restorations.

Acrylic removable partial dentures (RPDs) were prepared for patients allocated to the DRG. The surgical procedure was identical in both groups; however, in the DRG a collagen membrane (Bio-Gide®, Geistlich Biomaterials, Mediplus, Rixensart, Belgium: 25 x 25 mm) covering the implant (Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden) and the grafting material (Bio-Oss®, Geistlich Biomaterials, Mediplus, Rixensart, Belgium: 0.25 – 1 mm) was applied prior to wound closure. A RPD was used for 3 months in the DRG. Thereupon, the implant was uncovered and a provisional acrylic crown was connected. Clinical and radiographic evaluations were carried out at 3, 6 and 12 months following this time point. As in the IRG, provisional crowns were replaced by permanent ones after 6 months of function. Figure 7.1 gives an overview of the time frame. All surgical interventions were performed by one surgeon (JC) and all restorative ones by one prosthodontist (TDR). For a detailed description of these procedures, we refer to a recent paper (De Rouck et al. 2008b).

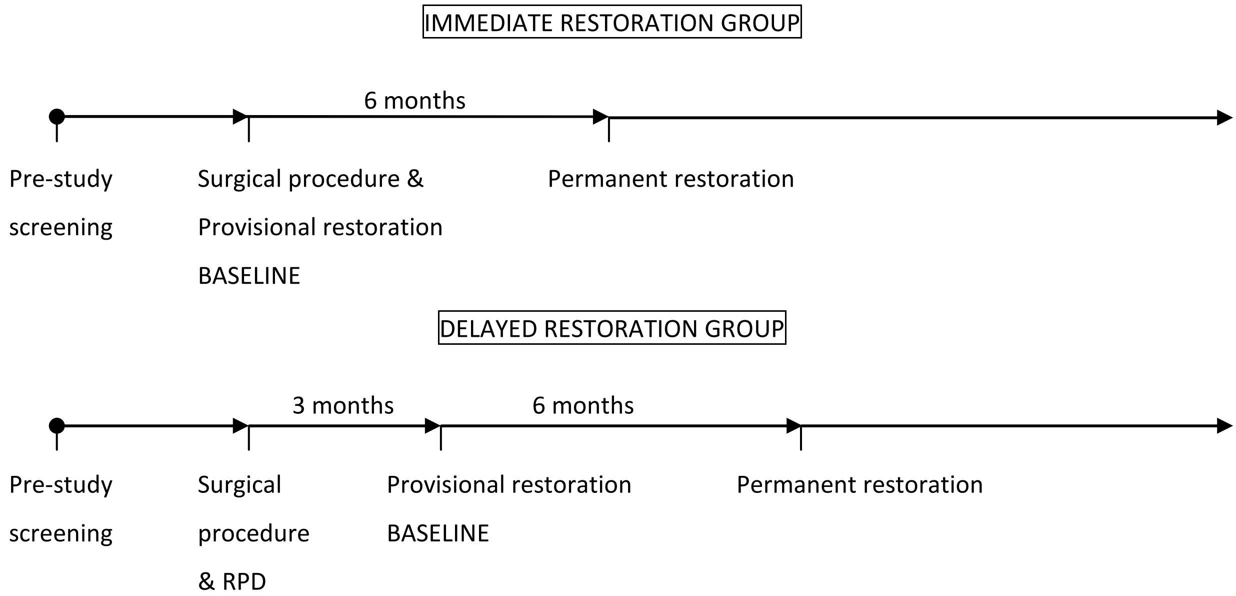

Figure 7.1 Treatment sequence of both protocols

Examination criteria

1. *Implant survival* evaluated at each occasion.
2. *Marginal bone level changes*. Standardized peri-apical radiographs were taken when the provisional crown was seated and at 3, 6 and 12 months follow-up. All were scanned, digitized and analyzed as previously described (De Rouck et al. 2008b).
3. *Plaque score* (0 = no visible plaque at the soft tissue margin; 1 = visible plaque at the soft tissue margin) was recorded at each re-assessment at 4 sites per implant (mesial, midfacial, distal, palatal).
4. *Probing depth* was measured at each re-assessment to the nearest 0.5 mm at 4 sites per implant using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, USA).
5. *Bleeding on probing* (0 = no bleeding; 1 = bleeding) was recorded at each re-assessment at 4 sites per implant.
6. *Papilla levels* were measured by means of an acrylic stent provided with direction grooves prior to tooth removal and at each re-assessment. A papilla level was defined as the distance between the top of the groove and the top of the papilla measured to the nearest 0.5 mm using a manual probe.
7. *Midfacial mucosa level* was recorded using the same acrylic stent provided with a central direction groove. It was defined as the distance between the top of the groove and the first contact with the peri-implant mucosa measured to the nearest 0.5 mm using a manual probe.
8. *Patient's esthetic satisfaction*. At study termination, patients were asked to express their satisfaction in terms of esthetic outcome on the basis of a 10 cm visual analogue scale labeled with 'not at all satisfied' at the zero point and 'completely satisfied' at the right end point.

To ensure blinding all examinations were performed by one clinician (IW) who had not been involved in any treatment.

Sample size calculation

Calculations were based on data from a case cohort study on immediate single-tooth implants (De Rouck et al. 2008b). A difference in soft tissue dimensions of 0.5 mm between the groups was defined as clinically relevant. Based on standard deviations of 0.7 mm for both groups, an alpha error level of 5% and statistical power of 80%, a sample size of 24 patients per group was calculated. In this study 26 patients per group were recruited.

Statistical analysis

The Chi-Square test was applied to evaluate matching of the groups in terms of implant position, diameter and length. For all parameters mean values and standard deviations were calculated. If data were normally distributed as assessed by the Shapiro-Wilk test, changes over time within each group (within group comparison) and the impact of treatment strategy (between group comparison) were examined by means of repeated measures ANOVA. Treatment strategy, time and their interaction were modeled as fixed factors and the patient as a random factor. If data failed to approximate a normal distribution, the Friedman test was used to seek for within group differences. Post hoc tests included Wilcoxon signed ranks tests adjusted for multiple comparisons. Between group comparisons were performed using the Mann-Whitney test. The level of significance was set at 5 %.

RESULTS

From the 52 patients that had been recruited, 49 were included in the study (IRG: 24 patients, 11 males and 13 females with a mean age of 55 years (SD: 13); DRG: 25 patients, 12 males and 13 females with a mean age of 52 years (SD: 12)). In two patients the labial crest was partially lost following tooth removal. Another patient listed for immediate restoration was excluded as the insertion torque was only 20 Ncm.

In both groups incisor and canine replacements accounted for more than 60 % of the cases. The most prevalent implant diameter was 4.3 mm (20 in IRG; 15 in DRG). 14 implants in both groups had a length of 16 mm. There were no significant differences between the groups in terms of implant position, diameter and length ($p \geq 0.110$). Table 7.1 gives an overview of the reasons for tooth loss sorted per tooth type and group.

Table.7.1 Descriptive statistics on reasons for tooth failure

	Incisor replacements		Canine replacements		Premolar replacements	
	IRG	DRG	IRG	DRG	IRG	DRG
Tooth fracture	5	4	0	0	2	3
Caries/Endodontic failure	3	4	1	2	3	3
Periodontal failure	4	3	1	2	2	3
Root resorption	1	1	1	0	1	0
TOTAL	13	12	3	4	8	9

IRG: Immediate Restoration Group
DRG: Delayed Restoration Group

Implant survival

In the IRG, one implant was lost due to mobility after one month resulting in a cumulative survival rate of 96 %. In the DRG two implants were removed: one as a result of mobility, another as a result of pain after 3 months. Hence, the cumulative survival rate was 92 % in the DRG.

Marginal bone level changes

Changes in bone levels from the time point of connecting the provisional restorations are shown in table 7.2. Bone loss significantly continued over time in both groups pointing to less than 1 mm at study termination. Only at 6 months, distal bone loss was significantly lower in the IRG in comparison to the DRG (p = 0.041).

Table 7.2. Decrease in marginal bone levels in relation to the time point of connecting the provisional restoration

Parameter	Treatment strategy	Month 3	Month 6	Month 12
Mesial (mm)	IRG	0.47 (0.29)	0.75 (0.44) §	0.92 (0.49) #
	DRG	0.61 (0.26)	0.89 (0.26) §	0.96 (0.25) #†
Distal (mm)	IRG	0.57 (0.65)	0.71 (0.73) §	0.79 (0.54) #
	DRG	0.53 (0.32)	0.87 (0.35) §*	0.97 (0.35) #†

Mean (SD)
IRG: Immediate Restoration Group
DRG: Delayed Restoration Group
§ Significant within group difference between 3 and 6 months
# Significant within group difference between 3 and 12 months
† Significant within group difference between 6 and 12 months
* Significant between group difference

Clinical conditions

Table 7.3 shows clinical conditions of implant restorations. There were nor within group, neither between group differences for any of the parameters.

Table 7.3. Clinical conditions of implant restorations at different time intervals

Parameter	Treatment strategy	Month 3	Month 6	Month 12
Plaque score	IRG	16 (15)	18 (19)	16 (15)
(%)	DRG	15 (18)	19 (17)	17 (18)
Probing depth (mm)	IRG	3.70 (0.69)	3.67 (0.75)	3.60 (0.61)
	DRG	3.65 (0.57)	3.36 (0.62)	3.27 (0.53)
Bleeding on probing (%)	IRG	38 (18)	44 (19)	40 (13)
	DRG	39 (20)	39 (13)	36 (13)

Mean (SD)
IRG: Immediate Restoration Group
DRG: Delayed Restoration Group

Soft tissue dimensions

Table 4 shows soft tissue level changes in relation to the pre-operative status. The largest amount of papilla loss was recorded at the 3 month re-assessment in both groups. Significant papilla regeneration was observed in the DRG thereafter, limiting the loss to approximately 0.5 mm at study termination. By and large, mean papilla shrinkage was about twice as high in the DRG when compared to the IRG at 3 months. There were, however, no significant differences in terms of papilla levels between the groups at any time point.

Midfacial soft tissue loss showed little to no variation over time in the IRG as well as in the DRG. However, the amount of apical displacement at the midfacial aspect was systematically 2.5 to 3 times higher in the DRG, showing a mean difference of 0.75 mm at study termination favoring immediate restoration (p = 0.005).

Table 7.4. Loss in soft tissue dimensions in relation to the pre-operative status

Parameter	Treatment strategy	Month 3	Month 6	Month 12
Mesial papilla level (mm)	IRG	0.53 (0.84)	0.41 (0.83)	0.44 (0.77)
	DRG	0.87 (0.48)	0.60 (0.43) §	0.43 (0.42) #
Distal papilla level (mm)	IRG	0.41 (0.80)	0.34 (0.81)	0.31 (0.81)
	DRG	0.87 (0.69)	0.63 (0.61)	0.53 (0.55) #
Midfacial mucosa level (mm)	IRG	0.47 (0.78)	0.47 (0.72)	0.41 (0.75)
	DRG	1.19 (0.75) *	1.16 (0.64) *	1.16 (0.66) *

Mean (SD)
IRG: Immediate Restoration Group
DRG: Delayed Restoration Group
§ Significant within group difference between 3 and 6 months
# Significant within group difference between 3 and 12 months
* Significant between group difference

Patient's esthetic satisfaction

Patient's esthetic satisfaction indicated on average 93 % (range: 82 - 100 %) for the IRG and 91 % (range: 80 - 96 %) for the DRG.

DISCUSSION

The results of the present study showed limited implant loss in the first year of function indicating immediate implant placement is predictable in terms of osseointegration (Smith & Zarb 1989). This finding is in accordance with previous studies (Gomez-Roman et al. 2001; Kan et al. 2003; Lorenzoni et al. 2003; Bianchi & Sanfilippo 2004; Cornelini et al. 2005; Tsirlis 2005; Juodzbalys & Wang 2007; De Rouck et al. 2008b). In addition, the amount of bone remodeling at the level of the alveolar crest was limited to less than 1 mm in both groups, which is also in line with published data (Lorenzoni et al. 2003; Bianchi & Sanfilippo 2004; Tsirlis 2005; Juodzbalys & Wang 2007).

The restorative procedure had no impact on clinical parameters such as probing depth and bleeding on probing in low plaque conditions. High bleeding scores around implants are common and usually explained by the presence of an inflammatory cell infiltrate at the level of the implant-abutment interface and the subgingival location of the restoration margin (Jemt & Pettersson 1993; Broggini et al. 2003).

The primary objective of this RCT was to study the impact of the restorative protocol on esthetics. Acrylic stents with fixed reference points were used to detect subtle changes over time in papilla and midfacial soft tissue levels. As previously described, the method was found highly reproducible (De Rouck et al. 2008b). Our results indicated remarkable papilla loss compared to the pre-extraction situation pointing to 0.9 mm in the DRG at 3 months of function. The mean difference of approximately 0.5 mm for distal papillae in favor of immediate restoration nearly reached the level of significance (p = 0.09). In this regard, the 3-month time span preceding temporary crown installation in the DRG, during which patients used a RPD, is imperative. As fixed contact points were lost in this period of time, papillae went down. In contrast, papillae were at all times supported by a provisional crown in the IRG limiting the amount of shrinkage to about 0.5 mm as shown by our data and previous findings (Kan et al. 2003). Interestingly, after the 3-month re-assessment the DRG seemed to catch up with the IRG in terms of papilla levels. This spontaneous regeneration of papillae has been earlier described and seems a common phenomenon at conventionally-inserted single-tooth implants (Jemt 1997; Grunder 2000; Cardaropoli et al. 2006). The amount of interproximal refill is believed to be strongly related to the level of the bone peak at the adjacent tooth (Choquet et al. 2001). Our data showed that comparable regeneration of papillae occurred following immediate implant placement and submerged healing. This RCT also indicated that restorative procedures did not influence the presence of papillae in the long term.

The amount of midfacial soft tissue loss showed virtually no variation over time in both groups, indicative of a steady state. The IRG indicated an average apical displacement of about 0.5 mm, which is in accordance with previous studies (Kan et al. 2003; Cornelini et al. 2005; De Rouck et al. 2008b). When comparing treatment strategies, however, recession was systematically 2.5 to 3 times higher in the DRG pointing to a mean additional loss of 0.75 mm in case of submerged healing. This disparity is detrimental in terms of esthetics and is explained as follows: (1) Primary wound closure was incomplete in all cases of the DRG as no attempt was made to perform vertical incisions and release of the periosteum. Consequently, membrane exposure occurred possibly causing some inflammation, additional bone and soft tissue loss. (2) The soft tissues were allowed to collapse in the DRG during a 3-month period, whereas they were constantly supported in the IRG. These findings support the need for instant provisionalization of immediate single-tooth implants in the interest of optimal midfacial esthetics. Interestingly, when single-tooth implants are inserted into healed sites this seems less critical, as Hall and co-workers (2007) described similar soft tissue levels for conventionally as for immediately restored fixtures after one year of function.

The extra soft tissue loss in the DRG of this study was basically unnoticed by the patients since patient's esthetic satisfaction was comparable in both groups. In this regard, one should realize that the professional evaluation and the patient's opinion of esthetics do not necessarily correlate (Meijndert et al. 2007).

In conclusion, immediate single-tooth implants should be instantly provisionalized to limit the amount of midfacial soft tissue loss. Our results may suggest the need for soft tissue augmentation if the primary implant stability does not allow immediate provisionalization.

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Chapter 8

Prosthetic considerations
for the immediate single-tooth implant

Restorative key elements for a predictable esthetic outcome of immediate single-tooth implants

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ABSTRACT

Achieving a satisfying esthetic result with an immediately installed single-tooth implant supported restoration is a challenge. By respecting four essential restorative factors the clinician can optimize his/her chances to achieve the utmost esthetic outcome. A first step is to instantly provisionalize the immediate single-tooth implant in light of optimal soft tissue preservation. Second, the provisional restoration should meet a number of morphological prerequisites. A third restorative factor consists in the replication of the meticulously formed soft tissue architecture for the permanent restoration to avoid subsequent soft tissue changes. And finally a fourth factor decisive for success relates to the choice of the abutment material.

This report gives a detailed description of these restorative key elements and illustrates a method for immediate replacement of a failing tooth with an implant-supported fixed prosthesis.

INTRODUCTION

Single-tooth replacements by means of endosseous implants have shown predictable treatment outcome (Jemt & Pettersson 1993, Ekfeldt et al. 1994, Andersson et al. 1995, Henry et al. 1996). The original implant protocol included implantation 3-6 months after tooth extraction and functional loading 3-6 months after implant insertion. Ever since, several studies have been published, mainly investigating the effects on implant survival when shortening the classical post-extraction healing and loading periods (Randow et al. 1999, Ericsson et al. 2000). As implant survival and success rates presented similar results compared to the original protocol, esthetics became the main focus of interest especially in the anterior maxilla. As a result of increasing esthetic demands and the ongoing quest to reduce treatment time, some authors combined immediate implantation with immediate provisionalization to replace a single maxillary tooth (Chaushu et al. 2001, Lorenzoni et al. 2003, Kan et al. 2003, Ferrara et al. 2006, De Rouck et al. 2008a). Often cited advantages of this strategy include patient's comfort, satisfying esthetic results and time management. Still, achieving a single-tooth implant restoration with a 'natural' appearance in harmony with the surrounding teeth and tissues remains a challenge. This report gives a detailed description of the restorative key elements decisive for a successful esthetic treatment outcome when pursuing immediate single-tooth replacement.

CASE

Patient's history

In 2005 a 75-year-old woman came in the Dental Clinic of the Free University of Brussels (VUB) with a crown fracture of the right lateral incisor. The tooth already had a history of restorative treatments at that time. In 1996, a profound cervical caries laesion was found (fig.8.1.a), which necessitated root canal treatment. With the intention to reinforce the remaining tooth structure a metal-ceramic crown restoration was proposed, but the patient insisted to reconstruct the tooth with composites (fig.8.1.b). After 9 years, this approach resulted in a subgingival crown fracture (fig.8.1.c & 8.2).

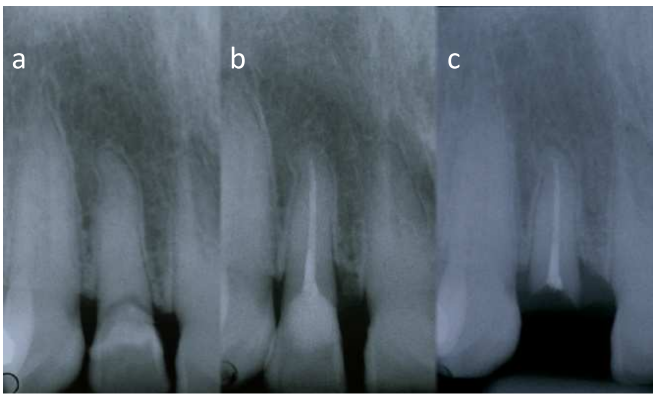

Figure 8.1.a: X-ray of the right lateral incisor with profound cervical caries (1996)

Figure 8.1.b: X-ray of the restored right lateral incisor (1996)

Figure 8.1.c: X-ray of the right lateral incisor with deep subgingival crown fracture (2005)

Figure 8.2: Clinical view of the fractured tooth (12)

Treatment plan

Since the plane of the fracture was situated deep beneath the gingival margin the long-term prognosis of the remaining root was judged doubtful. Therefore, tooth extraction was proposed. In order to accurately inform the patient about all feasible restorative options, the remaining root and surrounding tissues were submitted to a thorough clinical and radiographic examination. The failing tooth and adjacent teeth showed healthy periodontal conditions (probing pocket depth ≤ 3 mm) with normal interproximal bone levels; yet, a minor peri-apical laesion (fig. 8.1.c). The available restorative options were discussed with the patient, which included placement of a removable partial denture, a fixed partial denture, or an implant restoration. The patient preferred implant therapy since it was considered a predicable long-term approach avoiding preparation of intact adjacent teeth. However, she opposed to the idea of wearing a removable prosthesis during the healing phase. In light of this request, it was verified whether the patient met the necessary prerequisites for immediate implantation and provisionalization. Details on these requirements have been described in a recent paper (De Rouck et al. 2008b). Briefly, 3 prerequisites related to the hard tissues need to be taken into account:

1. The implant site cannot show major peri-apical infections.
2. The presence of at least 5 mm bone in height above the extraction socket is required as this bone volume ensures primary stability of a long implant crossing the apical portion of the socket.
3. Buccal bone defects extending to the buccal crest necessitate guided bone regeneration and thus flap closure, which essentially exclude the immediate connection of a temporary restoration.

3 prerequisites related to the soft tissues are as follows:

1. Healthy soft tissue conditions are a prerequisite for implant therapy.
2. An ideal soft tissue contour to slight overgrowth is compatible with a preservation-oriented strategy, whereas soft tissue recession requires reconstruction and thus a more staged approach.
3. Patients with a thin-scalloped gingival biotype are at risk for buccal bone resorption and gingival recession. These may require hard and/or soft tissue grafting and are therefore not ideal candidates for immediate tooth replacement.

As a correct three-dimensional implant positioning in an extraction socket is very difficult to achieve, an experienced surgeon is one of the most important requirements for success.

Since the implant site fulfilled these prerequisites and an experienced surgeon (JC) was involved, the risks and benefits of the latter treatment were discussed with the patient. In this regard, the patient had to be informed of a possible adjustment in treatment plan during surgery if the implant primary stability would become less than 35 Ncm. This value was considered a minimum for immediate provisionalization by means of an implant-supported crown. The patient agreed with the proposed treatment and expressed great enthusiasm for having the failing tooth immediately replaced.

Surgical procedure

Preoperative preparations

Prior to surgery, a preliminary polyvinyl siloxane putty impression (Elite H-D+ Putty Soft, Zhermack, Badia Polesine, Italy) was made using a plastic stock tray (Solo® Tray, J&S Davis, Herts, United Kingdom). Special care was taken to obtain an accurate impression of the tooth that needed replacement and the adjacent teeth. Thereupon, the putty impression was slightly adjusted as follows: redundant material and undercuts were removed and the putty and plastic tray were perforated at the tooth requiring the implant-supported restoration. The hole was made using a silicone bur and was made wide enough to provide an easy fit of an open tray impression coping. Since the adjusted putty impression would be used as impression tray during implant surgery, it was disinfected (Corsodyl mouthwash, GlaxoSmithKline, Genval, Belgium). Finally, an impression with an irreversible hydrocolloid of the opposing dental arch was made to facilitate adequate visualization of the occlusion and articulation afterwards.

One hour pre-operatively, antibiotic (Amoxicillin 500 mg) and analgesic (Ibuprofen 600 mg) therapy were started. Thereupon, the patient rinsed with a 0.2 % chlorhexidine digluconate solution (Corsodyl mouthwash, GlaxoSmithKline, Genval, Belgium).

Implant placement and impression for a provisional restoration

Surgery was performed under local anesthesia. For a detailed description of the procedure, we wish to refer to a recent paper (De Rouck et al. 2008a). Briefly, the remaining root was removed using periotomes following minimal mucoperiostal flap elevation. Special care was taken to preserve the bony walls of the socket especially the vestibular one. A 4.3 mm implant (Nobelreplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden) was installed in the fresh extraction socket with proper three-dimensional orientation (De Rouck et al. 2008a). In order to achieve primary implant stability of at least 35 Ncm, the palatal socket wall was engaged and a 16 mm implant was selected, which extended at least 4 to 5 mm beyond the apex of the extraction socket. Following confirmation of the primary stability using a torque controller (Nobel Biocare, Göteborg, Sweden), the implant impression could be made. The impression coping was connected to the implant (fig.8.3) and the flap was closed around the coping to avoid impression material from penetrating the wound. The prepared putty impression was placed and controlled for any interference with the impression coping. Subsequently, the final implant position was recorded using radio-opaque and sterile vinylpolysiloxane material (Elite implant® medium, Zhermack, Badia Polesine, Italy) (fig.8.4). After ensuring that no impression material had remained at the surgical site, a cover screw was attached to the implant and grafting material (Bio-Oss® 0.25

mm – 1 mm, Geistlich Biomaterials, Wolhusen, Switzerland) soaked in blood was inserted to fill the void between the implant and the alveolus. Finally, the cover screw was replaced by an appropriate healing abutment and the wound was closed by means of single sutures (Vicryl® 5/0, Johnson & Johnson, St-Stevens-Woluwe, Belgium).

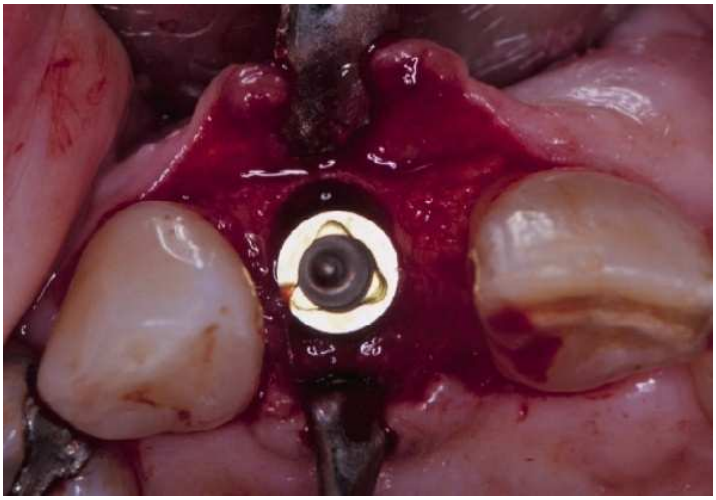

Figure 8.3 Minimal mucoperiosteal flap reflection and three-dimensional implant placement (Nobelreplace tapered TiUnite® diameter 4.3 mm - length 16 mm).

Figure 8.4 Impression of the final implant position with a radio-opaque and sterile

vinylpolysiloxane material (Elite implant® medium, Zhermack, Badia Polesine, Italy)

Postoperative instructions

Postoperative instructions included avoidance of the surgical site while brushing and eating, the use of a 0.2 % chlorhexidine digluconate mouthwash (Corsodyl mouthwash, GlaxoSmithKline, Genval, Belgium) 2 times a day for 2 weeks. Antibiotic and analgesic therapy were continued for 5 days, respectively 3 days. The patient was also instructed to avoid the site while eating during an 8 week period.

Restorative procedures

Provisional restoration

Using the implant impression taken at the time of surgery, an individualized screw-retained provisional crown was fabricated in the dental laboratory. An engaging titanium temporary abutment (Nobel Biocare, Göteborg, Sweden) served as a carrier for an appropriate hollowed denture tooth. Selection of the latter was principally driven by design and color of the failing tooth. Autopolymerizing acrylic resin (Palavit® 55 VS, Heraeus Kulzer, Hanau, Germany) was used to bond the temporary abutment to the denture tooth and for designing the cervical portion of the restoration. Prior to the application of autopolymerizing acrylic resin, the abutment was secured onto the implant replica with the long screw of the impression coping. This was done since the long screw protrudes above the occlusal plane or incisal edge of the provisional crown hereby securing a pathway for the screw of the provisional abutment. As a model of the opponent jaw was made, the provisional restoration was adjusted to clear centric and eccentric contacts prior to polishing and disinfecting procedures (fig.8.5).

Figure 8.5 Provisional restoration, autopolymerizing acrylic resin is used to bond a denture tooth to a temporary titanium abutment.

Intra-orally, the healing abutment was removed, the provisional restoration fit and minor adjustments were made to make sure the restoration was free of all contacts. Special attention was also given to the emergence profile. Fig. 8.6 & 8.7 illustrate a failure in this respect. It is of pivotal importance not to oversize the cervical area of the restoration: pressure to the buccal soft tissues may result in recession and rather unpredictable reconstructive surgery may be the only solution left to restore esthetics. Also, the contact points of the provisional restoration were located within 5 mm to the implant platform.

Figure 8.6 Oversized cervical emergence profile of the restoration (left), resulting in pressure to the buccal soft tissues and recession of the soft tissues (right).

Figure 8.7 Corrected cervical emergence profile of the restoration (left) and permanent restoration after supplementary reconstructive soft tissue surgery (right).

After a final polish and disinfection, the provisional restoration was secured onto the implant with the abutment screw and tightened using the torque wrench to 15 Ncm. The access hole to the abutment screw was filled with a small cotton and temporary restorative material (Cavit W, 3M Espe, Seefeld, Germany) (fig.8.8).

Figure 8.8 Labial view of the provisional screw-retained restoration
after 3 months of follow-up.

Permanent restoration

Six months after implant surgery the provisional restoration was replaced by a cemented permanent restoration. Special attention was given to an accurate replication of the emergence profile obtained by the provisional restoration as illustrated by a similar case (fig.8.11): first, the gingival border was intra-orally marked onto the provisional restoration with a pencil line, thereby visualizing the subgingival part extra-orally. Once out of the mouth, the subgingival part was copied by mounting the crown onto an implant replica, and by imbedding the replica and subgingival part into a putty with a hard consistency (Belosil HART, equator lab supplies, Genth, Belgium). After setting of the putty the supragingival part (incisal to the pencil line) was cut away. Thereupon, the provisional restoration was disconnected from the replica and replaced by a standard impression coping. The void between the putty and coping was filled with autopolymerizing acrylic resin (Palavit® G, Heraeus Kulzer, Wehrheim, Germany). Finally, this individualized impression coping was used to make a standard implant impression as previously described. In order to provide all information the dental technician received the 'individualized' impression together with the putty cast, which may serve as an extra aid to fabricate a customized abutment.

The right lateral incisor was restoratively treated by means of a zirconium abutment (Procera Abutment, Nobel Biocare, Göteborg, Sweden) and an all-ceramic crown with an aluminum oxide coping. The permanent abutment was torqued to 35 Ncm and the permanent restoration was cemented using temporary cement (Temp-Bond® NE, Kerr, Scafati, Italy) (fig.8.9 & 8.10).

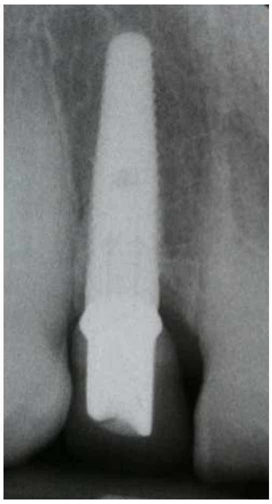

Figure 8.9 Permanent restoration after a follow-up period of 1 year.

Figure 8.10 X-ray of the permanent restoration after a follow-up period of 1 year.

In subsequent cases the procedure was refined and the individualized coping was adapted in such a manner that it could help to simplify clinical decision-making for abutment materials. Instead of using autopolymerizing resin to duplicate the subgingival profile as described above, flowable composite can be used. By using this white colored restoration material the clinician is able to imitate the esthetic benefits of a zirconium abutment. On the other hand, the clinician may also imitate the transparency of a titanium abutment through the soft tissue margin by coloring the composite emergence profile in grey or black (fig.8.11). Clearly, if the dark color is not visible through the soft tissues, the need for an expensive ceramic abutment may not be justified. Based on this criterion, the clinician and patient can make a well-considered decision in the choice of abutment material.

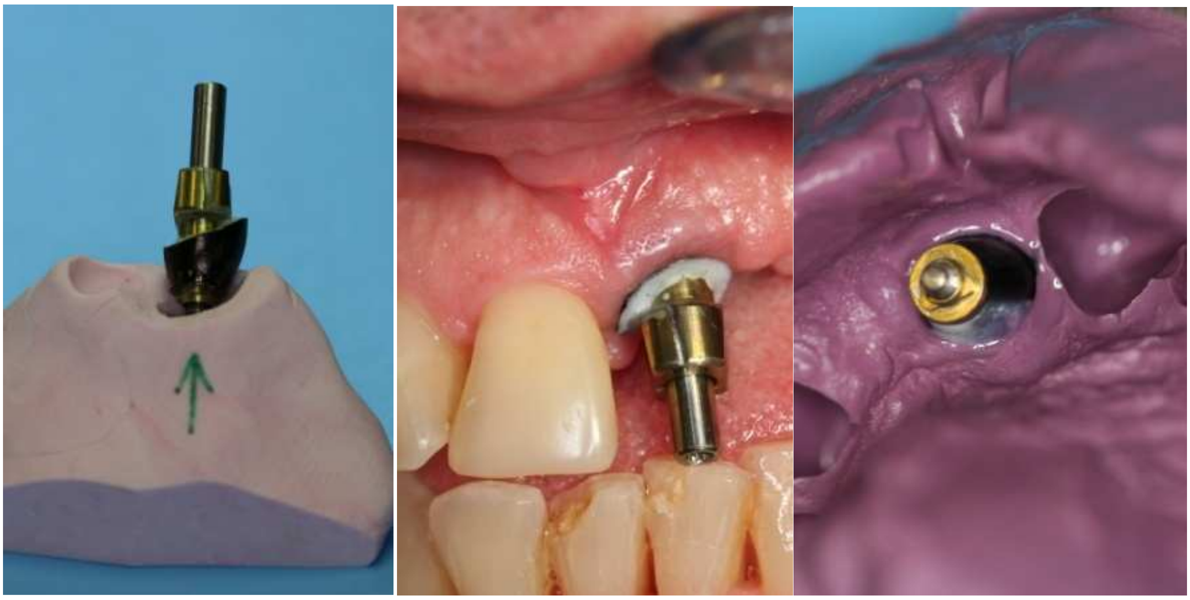

Figure 8.11 The individualized impression coping with a black colored emergence profile together with the putty cast (left), clinical view of the influence of a black emergence profile (titanium) on the mucosa transparency (middle), the 'individualized' impression (right).

DISCUSSION

This case illustrates a method for immediate replacement of a failing tooth with an implant-supported fixed prosthesis. For the patient, this appears an inviting strategy: it is a one-stage procedure and eliminates the need for a removable partial denture in the early stages of healing. Hereby, the patient benefits from immediate esthetics and comfort. From a clinical point of view, the procedure has also its obvious advantages: as it combines tooth extraction, implant surgery and restorative treatment, the time gain can be optimized. Although these benefits may be inviting in clinical practice, careful case selection remains of the utmost importance. At the very least, we believe that a number of prerequisites need to be fulfilled when an immediate single-tooth replacement is considered in the esthetic zone. After all, this procedure may potentially include higher risk for esthetic failure than conventional, more documented approaches (De Rouck et al. 2008b). Esthetic failure may be the result of improper case selection, surgical and/or restorative errors. Surgical factors have been discussed elsewhere and are essentially related to the selection of diameter-oversized implants and inaccurate three-dimensional implant positioning (Buser et al. 2004, Evans & Chen 2008, De Rouck et al. 2008b). Recent data have also shown that filling the marginal void between the buccal wall and the implant by means of bovine bone particles results in less bone resorption (Chen et al. 2007) and, by consequence less soft tissue shrinkage at the midfacial aspect of the restoration (Cornelini et al. 2004), which is in the interest of optimal esthetics.

Besides proper case selection and surgical aspects the esthetic outcome of immediate single-tooth replacements is also influenced by at least 4 restorative factors, which are discussed below.

First, immediate single-tooth implants should be *instantly provisionalized* (De Rouck et al. 2009a). If this is not respected and a removable prosthesis is used during the early stages of healing, papillae will be lost and it will take up to one year to attain the same height. Even more important is a substantial loss of midfacial soft tissue. In fact, one of the reports of our research group showed an extra midfacial soft tissue shrinkage of 0.75 mm after one year for immediately installed single-implants, which had been provisionalized by means of a removable partial denture, versus immediate single-implants which had been provisionalized using a fixed restoration (De Rouck et al. 2009a).

Second, a number of *aspects related to the provisional restoration* are of pivotal importance for esthetic success. These essentially include the necessity of screw retention on one hand and morphological aspects of the crown on the other hand. With an uncontaminated wound healing in mind, a screw-retained provisional restoration offers many advantages over a cemented one. Previously described methods for cement-retained provisional restorations come with some disadvantages (Maalhagh-Fard & Badr 2001, Dumbrigue et al. 2001, Schneider 2002, Ganddini et al. 2005). First, the marginal integrity may be inferior to provisional restorations made on a machine-fabricated implant component (Keith et al. 1999). Second, deep subgingival implant shoulders can create some difficulties to properly remove cement remnants. This may be the reason fistulae have been described when using cemented provisional restorations in the study by Kan et al. (2003). Moreover, instrumentation may produce scratches on the abutment and restoration (Agar et al. 1997). Third, cement-retained provisionals often require the selection and connection of the definitive abutment before reestablishment of the soft tissues (Dumbrigue et al. 2001, Schneider 2002). Finally, the intra-oral relining of a cemented provisional restoration might cause gingival irritation by contact with monomer of autopolymerizing acrylic resin, and might as such be detrimental for a proper wound healing. As the presented procedure is mainly performed in the laboratory/extra-orally, these potential irritations can be reduced.

When it comes to morphological aspects of the provisional crown, 3 regions should be carefully designed in the interest of optimal esthetics. That is, the incisal/occlusal region, the cervical region and the approximal region. Since micromovements during the early phases of healing may jeopardize the osseointegration process (Brunski 1993, Wiskott & Belser 1999, Brunski et al. 2000), we believe that the provisional crown should be clear of all contacts. In addition, it takes about 12 weeks before osseoperception has been established (El-Sheikh et al. 2003, Jacobs & van Steenberghe 2006). Even though the necessary adjustments can be done in the laboratory, intra-oral verification should be emphasized. Another key element is the cervical design of the crown facing the midfacial soft tissues. Figures 6 & 7 showed that pressure due to oversize may be detrimental and therefore should be avoided at all times. As the dental technician has little to no information on the midfacial soft tissue architecture, especially when a mucoperiosteal flap was raised, evaluation and possible correction of this critical area has to be done intra-orally. A final morphological key element relates to the approximal region and the position of the contact points in relation to the underlying bone peaks. In this regard, it is advised to locate the contact point of the implant-supported crown within a distance of 5 mm to the bone peak at the adjacent teeth. By doing so the clinician optimizes the preservation of papillae (Choquet et al. 2001). It is clear that individualization is necessary to maximally preserve the emergence profile and ultimate soft tissue configuration. Nevertheless, some soft tissue shrinkage of about 0.5 mm may be expected at the midfacial soft tissue level and papillary level during the early phases of healing (Kan et al. 2003, De Rouck et al. 2008a). Because of this phenomenon and because of the establishment of osseoperception (El-Sheikh et al. 2003, Jacobs & van Steenberghe 2006) and osseointegration, the permanent restoration is only installed after about 6 months. Evidently, all the key elements previously described for the provisional restoration are also of the utmost importance for the permanent one. Therefore, a third restorative factor should be respected and all the information, principally the soft tissue architecture, should be properly *transferred* to avoid subsequent soft tissue changes. In order to accurately do this, an individualized impression coping should be used. An easy method for customization has been described in this paper. A custom made abutment may be necessary in many cases to further optimize esthetics.

A fourth and final restorative factor decisive for success relates to the *choice of the abutment material*. A recent study has shown that about two thirds of the population presents a clear thick gingiva (De Rouck et al. 2009b). These subjects may not need a ceramic abutment since there will be no noteworthy transparency through the soft tissue margin. Indeed, in an in vitro study Jung et al. (2007) analyzed the effect of titanium and zirconium on the mucosa color of different thicknesses. Both restorative materials induced overall color changes when evaluated with a spectrophotometer, which diminished with increasing soft tissue thickness. However, with sufficient mucosa thickness no change in color could be distinguished by the human eye irrespective of the used restorative material. The authors concluded that mucosa thickness is a crucial factor in terms of discoloration caused by different restorative materials. In this respect it is not always evident for the clinician to make a decision concerning the abutment material. By adopting the above described method the clinician can make a more considerate decision. In this regard, the individualized impression coping does not only replicate the emergence profile but can also serve as a diagnostic device facilitating the choice of the appropriate abutment material (e.g. titanium or zirconium).

CONCLUSIONS

The presented protocol offers many advantages as well for the patient as for the clinician. This case illustrates that optimal esthetics can be obtained. However, careful patient selection, treatment planning and experienced clinicians seem of critical importance to accomplish this goal. At least 4 restorative key elements need to be taken into account.

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Chapter 9

General discussion, conclusions and recommendations

GENERAL DISCUSSION

Background

Nowadays, the clinician has the opportunity to choose between several treatment options to restore a single tooth gap. As success rates and predictability of single-tooth implants have improved, it becomes more and more the treatment of choice (Schmitt & Zarb 1993, Ekfeldt et al. 1994, Andersson et al. 1995, Henry et al. 1996). Essentially, single implant treatment includes four major modalities.

A first and most common procedure is the *conventional approach*. The implant is inserted in a fully-healed bone site either in a two-stage or a one-stage surgical approach. Several long-term studies illustrated its reliability as implant survival surpassed 93 % (Creugers et al. 2000, Krennmair et al. 2002, Romeo et al. 2002, Levin et al. 2006). Also mean peri-implant bone changes of approximately 1 mm during the first year of function and 0.05 mm annually thereafter were within a clinically acceptable range (Adell et al. 1986, Jemt & Pettersson 1993, Laney et al. 1994, Naert et al. 2002).

A second procedure is recommended when the buccal bone lacks volume to safely imbed the implant. In these cases *implant placement combined with guided bone regeneration*, is pursued. The success of this technique has been well-documented with survival percentages comparable with the conventional approach. Furthermore, combining implant placement with guided bone regeneration could lead to successful bone regeneration with stable peri-implant hard and soft tissue levels (Lorenzoni et al. 1999, Zitzmann et al. 2001, Hammerle & Lang 2001, Juodzbalys & Wang 2007).

Complexity further increases when the bone volume is totally insufficient to imbed the implant, hereby making a *staged surgical approach* inevitable including extensive bone grafting prior to implant placement. Usually, autogenous bone blocks are fixed with titanium screws onto the deficient alveolar ridge. After 6 months of healing re-opening is performed, the screws are removed and the implant is placed. This implies that it easily takes 9-12 months before an implant-supported restoration can be provided to the patient. The clinical and radiographic outcome following this strategy showed promising results with high implant survival rates and acceptable bone resorption (Jensen & Sindet-Pedersen 1991, Cordaro et al. 2002, Barone & Covani 2007).

A fourth and final treatment modality is the *immediate replacement* of a failing tooth with an implant-supported restoration (Tolman & Keller 1991, Gelb 1993, Polizzi et al. 2000, Gomez-Roman et al. 2001).

An important advantage of the latter procedure is the **reduced treatment time**. Indeed, by progressively shortening the healing period ultimately resulting in immediate implant placement and connection of an implant-retained provisional restoration, the time gain is optimized (Ericsson et al. 2000, Chaushu et al. 2001, Cooper et al. 2001, Andersen et al. 2002). This is particularly advantageous from a clinical point of view. In addition, the patient benefits from immediate esthetics and comfort, as only one surgical intervention is required and the need for a temporary removable denture during the healing phase is eliminated.

A second rationale in favor of immediate implantation is the potential to maximally preserve **hard tissues**. Since bone loss mainly occurs in the first 3 months after tooth extraction (Schropp et al. 2003), clinicians have been tempted to insert implants immediately after tooth loss, assuming bone remodeling would be reduced as such. At least Paolantonio and colleagues (2001) stated that the insertion of implants into a fresh extraction socket could prevent bone remodeling and hence maintain the bony crest structure. Some studies noted promising results concerning bone loss using the immediate implantation and provisionalization protocol (Kan et al. 2003a, Cornelini et al. 2005, Tsirlis 2005). The concept seemed at least as favorable in the short term as the conventional procedure, since the amount of hard tissue loss did not exceed 1 mm after one year of follow-up (Adell et al. 1986, Jemt & Pettersson 1993, Laney et al. 1994, Andersson et al. 1995, Goodacre et al. 1999).

A third motivation to combine immediate implant insertion with immediate provisionalization is to maximally preserve the **soft tissues**. As the soft tissue margins are strongly influenced by the bone changes induced by tooth extraction and every subsequent surgical intervention, it may be beneficial to adopt only one surgical intervention. Alternatively, the conventional procedure with 2 to 3 consecutive surgeries at the same site may result in more tissue damage and loss. In addition, the original soft tissue levels may be preserved by the instant connection of a provisional restoration offering a mechanical support to the papillae and midfacial gingival tissues, hereby possibly eliminating the need for additional soft tissue surgery. Earlier studies reported limited gingival recession after the first year following the above-proposed treatment strategy (Kan et al. 2003a, Cornelini et al. 2005). However, cautiousness when interpreting these results seems imperative as the lack of long-term results make conclusions premature. Furthermore, these data have been described in reference to a line connecting the midfacial soft tissue levels of the 2 adjacent teeth. Since this reference line is not necessarily stable over time, the use of a standardized measuring technique with fixed reference points is recommended.

Evidently, immediate implantation and provisionalization in the premaxilla is a tempting treatment strategy. Still, the potential advantages in terms of bone preservation may not hold true since recent animal experimental and clinical data have shown that bone remodeling at an extraction site inevitably occurs irrespective of the placement of an implant in the socket (Botticelli et al. 2004, Araujo et al. 2005). In turn, this could result in unpredictable soft tissue levels, making it a potentially risky procedure for esthetic failure if patients are not well-selected. We believe a number of prerequisites need to be simultaneously fulfilled when immediate implantation and provisionalization is considered in the anterior maxilla.

Patient selection

In spite of the promising results and high implant success rates, careful treatment planning and patient selection remains important. Every patient should be treated assessing his/her individual risks. Within the framework of a good patient selection the identification of the patient's *gingival biotype* is of great importance, since differences in gingival and osseous architecture have been shown to exhibit a different tissue response to surgical trauma (Olsson & Lindhe 1991, Kois 2001, Kao et al. 2008). In particular, the risk for esthetic failure may be limited in patients with a thick-flat biotype and would therefore qualify for immediate implant placement. Indeed, papilla presence between immediate single-tooth implants and adjacent teeth was significantly correlated with a thick-flat biotype (Romeo et al. 2008). In contrast, immediate implant placement should not be the treatment of choice for patients with a thin-scalloped gingival biotype. Since alveolar ridge resorption following tooth extraction is an inevitably event and bone loss will be more pronounced on the buccal than on the lingual aspect of the ridge (Schropp et al. 2003, Araujo & Lindhe 2005), these patients are more prone to develop buccal bone resorption. Needless to say, these inevitable bone changes may be detrimental for the management of the soft tissues resulting in additional midfacial recession (Evans & Chen 2008). This phenomenon is explained by the fact that a thin buccal bone crest is solely comprised of bundle bone which entirely resorbs following tooth removal (Araujo et al. 2005). In these high-risk patients, a staged procedure may be more predictable and therefore preferable. These observations and comments may emphasize the significant impact of the patient's gingival biotype on the outcome of the restorative treatment. In an attempt to identify high-risk patients for esthetic complications we conducted a study in 100 periodontally-healthy subjects using a simple method for the evaluation of gingival thickness. Three distinct groups of subjects could be identified using cluster analysis on the basis of 4 clinical parameters related to maxillary central incisors and their surrounding tissues, *i.e.* crown width/crown length ratio, width of the keratinized gingiva, papilla height and gingival thickness. The characteristics of two groups clearly corresponded with those of earlier introduced gingival biotypes (Weisgold 1977, Seibert & Lindhe 1989). Subjects classified as the thin gingival biotype presented a thin gingiva which included the following specific features: slender tooth form, relatively narrow zone of keratinized gingiva and a highly-scalloped gingival margin. On the other hand, patients with a thick biotype showed a clear thick gingiva, short and width teeth, a broad zone of keratinized gingiva and a flat, hardly scalloped gingival margin. In our study about two thirds of the subject sample showed high similarity with one of these biotypes (thick: 29% and thin 37%). However, the remaining part of the population (34 % of the subject sample) did not meet their description having features incommon with both of these extreme biotypes. These subjects showed a thick gingiva with slender teeth, a relatively narrow zone of keratinized tissue and a high gingival scallop.

As already described and supported by Evans & Chen (2008) and Romeo et al. (2008), we believe that patients with a thin-scalloped biotype should not be treated with an immediate single-tooth replacement. Our study confirmed the existence of distinct gingival biotypes using a simple visual method to assess gingival thickness as described by Kan et al. (2003b). That is, the transparency (thickness) of the free gingiva was evaluated by probing the midfacial pocket. The high intra-examiner repeatability of this method substantiated its usefulness. Furthermore, it is an easy and painless method, which can easily be applied in everyday practice without the need to purchase rather expensive ultrasonic devices. These may be relatively unavailable (Vandana & Savitha 2005) and difficult to handle (Daly & Wheeler 1971).

Apart from the gingival biotype, two other prerequisites related to the soft tissues need to be fulfilled for an immediate single-tooth replacement. That is, the soft tissues should be in a *healthy state* and if periodontal disease is present, it should be treated beforehand. In addition, an *ideal contour to slight excess* of soft tissues is a necessity as an immediate single-tooth replacement is a preservation-oriented strategy. If the soft tissue margin is unsatisfactory and recession is present prior to tooth removal, regeneration is warranted calling for a more conservative approach.

As part of a careful treatment planning and patient selection the clinician should verify 3 supplementary hard tissue requirements. First, the implantation area should *not show any* *signs of active infection*, which is usually accompanied by bone loss (Chen et al. 2004). Second, an adequate primary stability (> 35 Ncm) should be pursued, as it is one of the most important conditions to proceed with immediate loading (Lorenzoni et al. 2003, Ottoni et al. 2005). In order to ensure the best possible anchoring, it is desirable to choose an implant with a length that crosses the apical portion of the extraction socket. Thus, *sufficient bone volume* in this area is an important requirement. Additionally, sufficient primary stability can be attended by underpreparing the surgical site (Schwartz-Arad & Chaushu 1998, Friberg et al. 1999). The third hard tissue requirement implies that immediate provisionalization should not be performed in case of a *buccal bone defect* extending to the buccal crest because this condition requires guided bone regeneration and primary wound closure. In this regard, the clinician should be careful not to compromise the potential site during tooth removal.

Besides a meticulous patient selection, the experience of the surgeon also seems of critical importance, since a correct three-dimensional implant positioning in an extraction socket is difficult to achieve. Indeed, the extraction socket may force the drills in one, usually undesirable direction.

A final concern may be of restorative nature: the vertical and horizontal relation between the upper and lower jaw should permit the clinician to clear all contacts with the provisional restoration.

Throughout all clinical studies included in this thesis, all participating patients fulfilled the above described prerequisites necessary for immediate implantation and provisionalization.

Implant selection

Basically driven by the altering treatment objectives, the original protocol has strongly evolved during the last decades, resulting in higher demands of dental implants. In order to meet these demands, the implant design and surface topography have changed. In particular the micro-roughened *implant surface* has shown significant biomechanical advantages over the turned surface. The biological benefit implies an increase of the contact area with blood and thereby stimulating migration of osteogenic cells towards the implant surface. As such, contact osteogenesis is initiated (Park & Davies 2000, Park et al. 2001, Davies 2003). The mechanical advantage of a roughened implant includes an improved bone-to-implant contact (Ericsson et al. 1994). Hereby, the implant becomes more suitable and predicable in cases with poor bone quality or in cases where the surgical site necessitates a small-diameter or short implant (Weng et al. 2003, das Neves et al. 2006, Romeo et al. 2006). An additional benefit of the optimization of osseointegration is the time gain induced by the progressive shortening of the load-free healing period. As a result, a micro-roughened implant should be the first choice when the clinician considers immediate implantation.

Besides the importance of the implant microstructure, its *macrostructure* may also be of relevant influence. In fact, in an earlier report on immediate implantation and provisionalization by Chaushu and colleagues (2001) a low implant survival rate of 79% was observed. Their choice of implant type, which was a press-fit implant, may explain this disappointing result. In contrast, other studies revealed survival percentages surpassing 93 % using a screw-type implant (Groisman et al. 2003, Kan et al. 2003a, Cornelini et al. 2005, Tsirlis 2005). This observation seems evident as more bone-to-implant contact is found around screw-type implants (Vandamme et al. 2007). Furthermore, screw-type tapered implants may be preferred over screw-type cylindrical implants when considering immediate implantation and provisionalization since a tapered design allows for high primary stability (O'Sullivan et al. 2004).

Lately, implant companies have been promoting implants with micro-textured *collars*, as claimed, in the interest of hard tissue preservation and/or soft tissue integration. However, this trend may still be premature. Based on available literature the effect of micro-roughened implant necks on the management of the surrounding hard and soft tissues is currently unclear (Cosyn et al. 2007). Concerning the peri-implant remodeling the establishment of the biologic width is a pivotal factor (Berglundh & Lindhe 1996, Hermann et al. 2001). Other factors have been described showing a possible impact on crestal bone levels, such as the position of implant-abutment interface (Hermann et al. 1997, 2000), the concept of 'platform switching', implant necks with microthreads etc. Still, the additional value of these different implant designs remains questionable, since they have been poorly documented in long-term comparative studies so far. Moreover, in case of immediate implantation it can be difficult to predict the final buccal bone levels. Animal and human studies have shown that irrespective of the placement of an implant, post-extraction bone remodeling will occur mostly on the buccal aspect of the alveolar ridge (Botticelli et al. 2004, Araujo et al. 2005). Consequently, this phenomenon entails that in some immediate implantation cases a small part of the implant neck may end up supracrestally. Since the recently introduced roughened implant collars do not necessarily provide a better seal of the peri-implant mucosa (Comut et al. 2001, Abrahamsson et al. 2001), it might be safer to select an implant with a smooth collar. These smooth implant collars are less prone to plaque accumulation and as such, may be less vulnerable to peri-implant mucositis and peri-implantitis (Quirynen et al. 1996, Teughels et al. 2006).

In light of all these considerations, we choose to conduct our studies with screw-type tapered implants with a micro-roughened body and machined collar.

Implant survival

In our prospective study (chapter 6), thirty consecutive patients were treated for single-tooth replacement in the esthetic zone by means of immediate implant placement and provisionalization. All patients underwent the same strategy, that is minimal mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material between the implant and the socket wall and the connection of a screw-retained provisional restoration within the same day. Clinical and radiographic evaluation was completed at 1, 3, 6, and 12 months to assess implant survival and complications, hard and soft tissue parameters and patient's esthetic satisfaction. In our randomized controlled study on immediate implants (chapter 7) the goal was to compare the soft tissue outline at immediate implants following two restorative protocols: immediate connection of a temporary crown (24 patients) or submerged healing during which a removable partial denture was used (25 patients). Again the same clinical and radiographic parameters were assessed for both groups at the scheduled recall visits (3, 6, and 12 months). A correct three-dimensional implant orientation as described by Buser et al. (2004) implies that there will remain a gap between the implant and the buccal socket wall in most cases. We systematically filled-up this void using deproteinized bovine bone particles. Earlier studies demonstrated its benefit, as grafting this marginal void optimizes the preservation of the buccal bone (Chen et al. 2007), and offers an advantage in terms of soft tissue support (Cornelini et al. 2004).

Besides one early failure, all implants of the first prospective study remained well-integrated based on the success criteria for osseointegration proposed by Smith & Zarb (1989) resulting in a 97 % cumulative implant survival rate after one year of function. Similarly, in the randomized controlled study promising one-year implant survival was found: for the immediate restoration group this was 96 %; for the delayed restoration group 92 %.

From a historical perspective, the pioneer implant in immediate implantation is the Tübinger implant (Frialit I). In 1976 it was introduced to immediately replace the extracted root in the anterior area. Its shape had been specifically designed to fill up most of the alveolar void (Schulte & Heimke 1976). Although good initial results (Wagner et al. 1981), it was withdrawn from the market and eventually replaced by the titanium Frialit II implant, since the polycrystalline aluminum oxide implant (Frialit I) did not meet the expectations in terms of long-term stability (survival percentage of 87 % after 4.5 years and 53 % of the implants showed a marginal bone resorption of more than 2.5 mm) (De Wijs et al. 1994, 1996, Kohal et al. 2008). The titanium variant on the other hand did provide survival rates (> 94 %) comparable with the present results (Gomez-Roman et al. 2001, Lorenzoni et al. 2003, Ferrara et al. 2006). Furthermore, our obtained results were comparable to other short-term studies using the same protocol (94 %) (Hui et al. 2001, Calvo Guirado et al. 2002, Lorenzoni et al. 2003, Kan et al. 2003a, Cornelini et al. 2005, Ferrara et al. 2006, Barone et al. 2006, Ribeiro et al. 2008). Studies with longer observation periods reported survival rates of ≥ 93 % (Groisman et al. 2003, Norton 2004, Tsirlis 2005, Degidi et al. 2006). Interestingly, these survival rates are in line with data published for implants inserted according to the conventional approach (≥ 93 %) (Goodacre et al. 1999, Krennmair et al. 2002, Levin et al. 2006, Romeo et al. 2006). Hence, the time span from extraction to implant placement does not seem to be the pivotal factor in attaining osseointegration.

Clinical and radiographic outcome

In spite of the fact that plaque levels remained low throughout both studies (< 20 %), bleeding on probing scores were high. This is, however, not an uncommon feature around implants (Lorenzoni et al. 1999, Chang et al. 1999, Roos-Jansaker et al. 2006, Ozkan et al. 2007, Cosyn & De Rouck 2009) and may be the result of an 'inflammatory cell infiltrate' possibly induced by microleakage at the implant-abutment interface (Broggini et al. 2003, Piattelli et al. 2003) and the subgingival position of a restoration border (Jemt & Pettersson 1993).

Relatively high mean probing depth of about 3.5 mm after one year was recorded in both studies, which can be considered a normal phenomenon around two-piece implants as described by others (Lekholm et al. 1986, Apse et al. 1991, Proussaefs et al. 2002, Cosyn & De Rouck 2009). A further interesting observation was the tendency of pocket shrinkage towards the end of the studies, as earlier notified by Proussaefs et al. (2002) and Apse et al. (1991).

Radiographic examination revealed a mean bone loss limited to less than 1 mm, which was in line with other studies using the same treatment concept (Lorenzoni et al. 2003, Tsirlis 2005) and with the conventional two-stage protocol at healed sites (Adell et al. 1986, Naert et al. 2002). What is more, bone remodeling was not influenced by the restorative protocol, as no significant difference could be found between immediate or delayed provisionalization. This observation was confirmed by the results of a similar study demonstrating no statistically significant difference on crestal bone levels between both restorative protocols over two years (Crespi et al. 2008). Immediate implantation followed by a submerged healing period revealed similar mean crestal bone shrinkage of approximately 1 mm (Bianchi & Sanfilippo 2004, Juodzbalys & Wang 2007). These findings may contribute to the fact that the effect of the used restoration protocol on crestal bone remodeling is only of minor importance, but is dependent on the location of the microgap irrespective of submerged or non-submerged healing (Hermann et al. 2000, Cosyn et al. 2007).

Another observation was that the major part of marginal bone resorption occurred in the first 6 months. Between 6 and 12 months post placement an additional mean bone resorption of only 0.13 mm was recorded. In accordance with this result, Ericsson et al. (2000) presented similar data, when comparing immediate provisionalized single-tooth implants (0,14 mm) with the original two-stage concept (0,07 mm). This may indicate that the major part of the hard tissue remodeling takes place during the early phase of healing. Interestingly, this pattern of hard tissue remodeling coincides with stable soft tissue levels after 6 months (Small & Tarnow 2000). These figures should be the rationale to load the implant with a definitive prosthesis only 6 months after hard and soft tissue healing.

Based on these short-term clinical and radiographical results, immediate single-tooth implants in the anterior maxilla may be considered as a viable treatment strategy. However, cautiousness seems imperative since ample studies have been published on immediate implantation and provisionalization for replacing maxillary anterior teeth whereas only few have documented its esthetic treatment outcome (Belser et al. 2004).

Esthetic outcome

Although the immediate single-tooth implant has become an accepted treatment option, its success is merely based upon the success criteria proposed by Smith & Zarb (1989). These criteria only include survival rate (*i.e.* osseointegration) and hard tissue alterations, and do not consider the esthetic outcome of the final restoration. Since Implant Dentistry evolved from a bone-driven surgical procedure to a restoratively- and biologically-driven protocol, the esthetic success will be determined by the 'natural' appearance of the restoration in harmony with the surrounding teeth and tissues. Nowadays esthetics are not only dictated by the form and color of the crown, also peri-implant tissues contribute to the esthetics of a restoration (Fürhauser et al. 2005). In this regard, one should realize that the professional evaluation and the patient's opinion of esthetics do not necessarily correlate (Meijndert et al. 2007), and therefore, both should be taken into account in an esthetic evaluation.

The main objective of the present study was to evaluate the soft tissue alterations following immediate implant replacement of a single failing tooth in the premaxilla. Concerning these assessments soft tissue reductions of as well the papillae as the midfacial soft tissue level were limited to 0.5 mm throughout the whole study period.

Our randomized controlled study (chapter 7) revealed a significant influence of the restorative procedure on the soft tissue architecture. In this regard, it was remarkable that 3 months after connection of the provisional restoration the papilla levels differed approximately by 0.5 mm in favor of the immediate restoration group. This might be considered as a logic finding because the papillae were at all times supported by the provisional crown, whereas in the delayed restoration group the papillae collapsed during the 3 months of submucosal healing. Interestingly, the difference in papilla heights between both treatment strategies leveled out towards the end of the study. This result may indicate that the restorative procedure does not influence the presence of the papillae. This spontaneous regeneration of the papillae is in line with other studies (Jemt 1997, Grunder 2000, Cardaropoli et al. 2006) and seems principally dictated by the level of the contact point in relation to the bone peak at the adjacent tooth (Choquet et al. 2001). Still, at the one-year reassessment the papilla levels for both protocols were approximately 0.5 mm lower compared to the original situation with the failing tooth in place.

Also defining for esthetics is the significant difference in midfacial soft tissue loss between both protocols. In fact, additional midfacial soft tissue shrinkage of 0.75 mm after one year was found in case of submerged healing when compared to immediately restored single-implants. The reason for this significant disparity may be twofold: first, no attempt was made to perform vertical incisions and release of the periosteum. As such, primary wound closure in the delayed restoration group was difficult and incomplete. Consequently, the exposed membrane may have been susceptible to inflammation causing more soft tissue loss. Second, the soft tissues were allowed to collapse during the submerged healing period. Following the 3-month healing period, the soft tissues were again surgically manipulated for uncoverage. Only as of then, the peri-implant soft tissue complex could be established around the restoration. In contrast, by replacing the failing tooth at once the existing soft tissue complex could be immediately supported by the temporary fixed restoration. Interestingly, some loss of buccal soft tissue (0.5 mm) in relation to the pre-extraction data was recorded in spite of immediate provisionalization. This is in line with earlier observations (Kan et al. 2003a) and may be an inevitable event since alveolar ridge alterations occur following tooth extraction irrespective of immediate insertion of an implant (Botticelli et al. 2004, Araujo et al. 2005). From a clinical point of view this distinct response of the midfacial soft tissues to the restorative protocol may promote immediate provisionalization in those cases that meet the criteria for this procedure (De Rouck et al. 2008b).

Since the present report and the study by Kan et al. (2003a) following a similar strategy indicated comparable levels of papilla loss and midfacial soft tissue recession after one year of function, the possible impact of the flapless surgical approach seems negligible in the longer run. On the other hand, hard tissue remodeling is strongly influenced by the implant position. Since the soft tissue levels are indissoluble coupled with the underlying hard tissue structures and their changes, the three-dimensional implant position is of utmost importance. Evans & Chen (2008) have already pointed out that implants with a buccal shoulder position (at or buccal to the reference line between the cervical buccal position of the adjacent teeth following the line of the arch) showed a higher risk of mucosal recession than implants with a palatal shoulder position. Furthermore, we choose to systematically graft the void between implant and the extraction alveolus in order to engage every opportunity to preserve the existing bone structure, and thus soft tissue levels (Cornelini et al. 2004, Chen et al. 2007). Another precaution to ensure an uneventful and sound tissue maturation is to promote a screw-retained provisional restoration, to the detriment of a cement-retained provisional restoration. Subgingival cement remnants may cause soft tissue irritation and may eventually result in fistulae (Kan et al. 2003a).

Other studies on soft tissue topography have been published pointing to 0.6 mm midfacial recession in the first year of function following single-tooth implant placement in healed sites (Grunder 2000, Cardaropoli et al. 2006). However, cautiousness in interpreting these data seems imperative, since most of these soft tissue alterations were measured with respect to the gingival level at (provisional) crown connection, while our figures depict gingival changes in relation to the original situation (*i.e.* failing tooth in place). Consequently, the initial gingival shrinkage between second stage surgery and crown connection is not taken into account in these studies. In light of this remark, Small & Tarnow (2000) recorded 0.9 mm soft tissue recession in reference to the moment of transmucosal implant connection. By on average 3 years of follow-up, midfacial soft tissue loss of about 1 mm has been described for conventional single-tooth implant restorations (Chang et al. 1999). In addition, long-term studies have demonstrated ongoing soft tissue shrinkage up to 1.7 mm, at least in fully-edentulous patients (Adell et al. 1986, Apse et al. 1991). These findings indicate that remodeling is an inevitable and continuous event, making long-term soft tissue monitoring a necessity. Interestingly, our results demonstrated similar midfacial soft tissue shrinkage (1.16 mm) for immediate single-tooth implants in a delayed loading protocol, and were confirmed by recent measurements of soft tissue recession (0.9 mm) following the same protocol (Evans & Chen 2008). These findings support the need for instant provisionalization of immediate single-tooth implants to limit the amount of midfacial soft tissue loss in the interest of optimal esthetics. Another remarkable observation was that immediate provisionalization of a single-tooth implant inserted into healed sites seems less critical, as Hall and co-workers (2007) described similar soft tissue levels for conventionally as for immediately restored fixtures after one year of function.

In spite of the different soft tissue outcomes between various treatment protocols, this was not always translated into a differing patient's esthetical appreciation. Basically, the score on patient's esthetic satisfaction remained high irrespective of the treatment protocol (> 90 %). In this regard, one should realize that the professional evaluation and the patient's opinion of esthetics do not necessarily correlate (Meijndert et al. 2007).

In conclusion our results indicate that immediate implantation followed by immediate provisionalization has its advantages in terms of soft tissue support. By using this strategy the adjacent papillae will immediately be supported resulting in a minimal initial 0.5 mm loss in height. Concurrently midfacial soft tissue loss will be limited to approximately 0.5 mm after one year. All other treatment modalities, in which implants are not immediately installed and provisionalized, will not prevent the collapse of the soft tissues following an unsupported healing, resulting in a subsequent loss of soft tissue height. Although, these promising results on immediate replacements of a single failing tooth might be appealing for the clinician, these observations should be confirmed in long-term clinical studies. In addition, the esthetic treatment outcome should be compared to other modalities of single-implant treatment in the anterior maxilla.

Optimization of esthetic outcome

Apart from the influence of the surgical treatment on hard and soft tissue preservation some restorative key elements specifically with respect to the provisional restoration need to be taken into account. These essentially include the necessity of screw retention on the one hand and morphological features of the crown on the other hand.

With a clean wound healing in mind and based on four obvious advantages, a screw-retained provisional restoration was preferred instead of a cemented one. First, since the provisional restoration was made on a machine-fabricated implant component, the marginal integrity may be superior (Keith et al. 1999). Second, deep subgingival implant shoulders can create some difficulties to remove cement remnants properly. This may be the reason fistulae have been described when using cemented provisional restorations (Kan et al. 2003a). Moreover, instrumentation may produce scratches on the abutment and restoration (Agar et al. 1997). Third, cement-retained provisionals often require the selection and connection of the definitive abutment before reestablishment of the soft tissues (Dumbrigue et al. 2001, Schneider 2002). Finally, as the presented procedure is mainly performed in the laboratory/extra-orally, additional gingival irritations, such as contact with monomer of autopolymerizing acrylic resin, can be avoided. On the other hand, a screw retained restoration fails in the ability to compensate for labially angulated implants, resulting in an abutment screw emerging through the labial surface of the restoration. Even then, the esthetical interference will be of minor importance because the opening can be concealed with composite resin restorative material.

With respect to the morphological aspect of the restoration, three regions should be carefully designed in the interest of optimal esthetics. That is, the incisal/occlusal region, the cervical region and the approximal region. Absence of occlusion and articulation contacts should be assured to avoid excessive micromovements during the early phases of healing, which may be sufficient to jeopardize the osseointegration process (Brunski 1993, Wiskott & Belser 1999, Brunski et al. 2000). Another key element is to carefully design the cervical area. An oversized cervical design may lead to detrimental pressure resulting in midfacial soft tissue recession. A final morphological key element relates to the approximal region. In this regard, it is advised to locate the contact point of the implant-supported crown within a distance of 5 mm to the bone peak at the adjacent teeth. By doing so, the clinician optimizes the preservation of papillae (Choquet et al. 2001).

Six months after implant loading the provisional restoration may be replaced by a permanent one. Because of the initial soft tissue shrinkage during the early phases of healing (Kan et al. 2003a, De Rouck et al. 2008a) and because of the establishment of osseointegration and osseoperception (El-Sheikh et al. 2003, Jacobs & van Steenberghe 2006), the permanent restoration was only installed after about 6 months in our studies. Evidently, it is clear that special attention goes to the accurate replication of the meticulously formed soft tissue architecture for the permanent restoration to avoid subsequent soft tissue changes. Since support of the surrounding tissues should be a primary objective, a custom made abutment may be necessary for each individual situation. In order to ensure an accurate duplication of the emergence profile of the provisional restoration and to transfer the established emergence profile to the master cast for fabrication of the custom made abutment, an individualized impression coping could be used.

A further crucial factor in implant esthetics is the color of the peri-implant mucosa, mainly influenced by the gingival thickness (De Rouck et al. 2009) and the choice of abutment material. With respect to the increasing esthetic demands all-ceramic abutments were introduced as an alternative to commonly used titanium abutments (Andersson et al. 2001, Henriksson & Jemt 2003). However, the use of these ceramic abutments implicates extra costs for the patient, which are not always necessary in every case. In an in vitro study Jung et al. (2007) analyzed the effect of titanium and zirconium on the mucosa color of different thicknesses. Both restorative materials induced overall color changes when evaluated with a spectrophotometer, which diminished with increasing soft tissue thickness. However, with sufficient mucosa thickness no change in color could be distinguished by the human eye irrespective of the used restorative material. Based on these findings they concluded that mucosa thickness is a crucial factor in terms of discoloration caused by different restorative materials. In this respect it is not always evident for the clinician to make the right decision concerning the abutment material. As a result, a clear diagnostic method urged itself to visualize in advance the effect of the material choice on the mucosa color. Individualizing the impression coping with a white colored restoration material, such as a flowable composite, could help to visualize the esthetic effect of a zirconium abutment on the transparency of the marginal gingiva. On the other hand, the clinician may also imitate the transparency of a titanium abutment through the soft tissue margin by coloring the composite emergence profile in grey or black. Based on this test, the clinician can make a well-considered decision in the choice of abutment material, and may immediately illustrate his/her choice to the patient. Eventually, the individualized impression coping does not only replicate the emergence profile but can also serve as a diagnostic device facilitating the choice of the appropriate abutment material (e.g. titanium or zirconium).

CONCLUSIONS

In reference to the objectives as stated on page 49:

(a) A clear thin gingiva was found in about one third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced ‘thin-scalloped biotype’. A clear thick gingiva was found in about two thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced ‘thick-flat biotype’. The other half could not be classified as such. These subjects showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop.

(b) With regard to the macrodesign a screw-type tapered implant achieves the highest bone-to-implant contact resulting in the highest primary implant stability. Concerning the microstructure a roughened implant surface has shown significant biomechanical advantages. However, based on comparative studies currently available, it is unclear whether micro-roughened implant necks reduce crestal bone loss and/or stimulates soft tissue integration. By consequence, micro-roughened implant collars do not provide an obvious advantage. On the contrary, the long-term impact of these modified collars on the initiation and progression of peri-implant pathology is currently unknown.

(c) Short-term results on implant survival and hard tissue alterations were at least comparable to the outcome of the conventional procedure. Papillae loss and midfacial soft tissue shrinkage were limited to approximately 0.5 mm after one year of observation. Based on these hard and soft tissue outcomes, single-tooth replacement by means of mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material and the connection of a screw-retained provisional restoration can be considered a valuable treatment option.

(d) Whether the implant is immediately restored or not has no influence on osseointegration or bone remodeling. However, it has a greater impact on the soft tissues surrounding the implant. If the implant is not immediately provisionalized, papillae will be lost and it will take up to one year to attain the same height as when the implant is immediately restored. Even more important for esthetics is the loss of the midfacial soft tissue which showed a permanent character during the one year study period. If the condition of the selected case permits it, immediate provisionalization should be advised to minimize this soft tissue shrinkage.

(e) Some prosthetic considerations are crucial to achieve an optimal esthetic result. These essentially comprise four restorative key elements. A first one is to instantly provisionalize the immediate single-tooth implant in light of optimal soft tissue preservation. Second, the provisional restoration should meet a number of morphological features and in the interest of a sound tissue maturation a screw-retained provisional restoration is recommended. A third restorative factor consists of the replication of the meticulously conditioned soft tissue architecture for the permanent restoration to avoid subsequent soft tissue changes. And finally a fourth factor decisive for success relates to the correct choice of the abutment material.

RECOMMENDATIONS

With respect to the clinical practice:

Careful patient selection and treatment planning are of critical importance in achieving a predictable treatment outcome. The following prerequisites need to be respected:

1. **Soft tissue considerations**
    - The soft tissues should show a healthy condition.
    - The soft tissues surrounding the failing tooth present a similar contour or a slight overgrowth in comparison with the adjacent teeth. Soft tissue recession requires reconstruction and thus a more staged approach.
    - Patients with a thin-scalloped gingival biotype are at risk for buccal bone resorption and gingival recession. These may require hard and/or soft tissue grafting and are therefore not ideal candidates for immediate tooth replacement.
2. **Hard tissue considerations**
    - The implant site cannot show major peri-apical infections.
    - The presence of at least 5 mm bone in height above the extraction socket is required as this bone volume ensures primary stability of a long implant crossing the apical portion of the socket.
    - Buccal bone defects extending to the buccal crest necessitate guided bone regeneration and thus flap closure, which essentially exclude the immediate connection of a temporary restoration.
3. **Prosthetic considerations**
    - The vertical and horizontal relation between the upper and lower jaw should permit the clinician to clear all contacts with the provisional restoration.

Four restorative key elements are decisive to optimize the chances for an esthetic outcome.

1. **Instant provisionalization** of the immediate single-tooth implant in the light of optimal soft tissue preservation.
2. The **provisional restoration** should meet a number of aspects of critical importance for esthetic success:
    - The use of a *screw-retained provisional* restoration may promote an uncontaminated wound healing.
    - The *incisal/occlusal region* of the provisional crown should be cleared of all contacts in occlusion and articulation.
    - The *cervical design* of the crown should not be oversized as this may be detrimental for midfacial soft tissues.
    - At the *approximal regions* it is advised to locate the contact point of the implant-supported crown within a distance of 5 mm to the bone peak at the adjacent teeth. By doing so, the clinician optimizes the preservation of papillae.
3. Proper **replication** of the meticulously conditioned soft tissue architecture for the permanent restoration to avoid subsequent soft tissue changes.
4. The correct **choice of the abutment material** in relation to the transparency of the soft tissues.

With respect to future research:

Further investigation is necessary in order to understand and determine other factors which may influence the nature of the tissue biotype. An understanding of this natural variety may offer the practitioner some indications to predict the clinical outcome of certain restorative and surgical procedures.

Long-term prospective comparative studies using one implant system, monitoring crestal bone changes from fixture installation, are needed to elucidate the impact of collar surface roughness on bone remodeling.

Since soft and hard tissue remodeling is an inevitable and continuous event, further long-term prospective and controlled clinical studies are mandatory to document the esthetic treatment outcome of an immediately replaced failing tooth in the premaxilla with an implant-supported provisional restoration. A reproducible technique to monitor soft tissue levels as we proposed could be used in future research for this purpose.

Hitherto, there is little to no information on the comparison of the clinical, radiographic and aesthetic outcome of single implant treatment following various modalities. If future research should indicate that relevant disparities exist, the impact on clinical decision making becomes apparent.

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SUMMARY

The loss of a single tooth in the esthetic area is for most patients a traumatic event. Nowadays, several treatment modalities are available to replace the failing tooth, such as a resin-bonded restoration or a conventional fixed partial denture. However, since the introduction of implants several decades ago and the increasing body of evidence on the predictability of this alternative, the popularity of the single-tooth implant has increased tremendously. Originally, an initial period of 3 to 6 months of submerged healing was advocated, followed by a second surgical intervention to uncover the implant. Yet, this prolonged treatment time may be considered an important reason to abandon the implant-supported restoration as the treatment of choice by some patients. In light of this argument several clinicians became tempted to insert implants shortly to immediately after extraction and to restore likewise following implant placement (chapter 1).

In chapter 2 a review on immediate replacement of a failing tooth in the premaxilla showed that implant survival and even managing the hard tissue levels seem predictable. Survival rates in this limited number of studies were at least comparable to the original protocol and presented promising peri-implant bone loss not surpassing 1 mm. Yet, in the past decade the criteria for success have changed in the interest of an esthetic treatment outcome and as such, the influence of soft tissue changes became of critical importance. Although the papilla levels seemed predictable since these are hardly influenced by the surgical/restorative protocol, maintenance of the midfacial soft tissue levels seemed less predictable. As currently available information on this topic is very scarce, the clinician should be reserved when considering immediate implant placement and provisionalization for replacing single maxillary teeth in the esthetic zone. At the very least, a number of guidelines and prerequisites need to be taken into consideration.

The overall aim of this thesis was to elucidate these guidelines and prerequisites, and to evaluate the short-term esthetic outcome of immediate single-tooth implant restorations in the anterior maxilla. Key questions in this respect relate to patient selection, implant selection and treatment protocol (chapter 3).

In reference to proper patient selection, the gingival biotype is of particular interest for the clinician, as patients with a thin-scalloped gingival biotype present a higher risk for esthetic complications. Based on this knowledge patients with a thin gingival biotype were systematically excluded from the conducted studies on immediate tooth replacement. The prevalence of the different gingival biotypes was investigated in chapter 4. Out of a large group of young adults 3 clusters with specific features could be identified using simple diagnostic methods. A clear thin gingiva was found in about one third of the sample in mainly female subjects with slender teeth, a narrow zone of keratinized tissue and a highly scalloped gingival margin corresponding to the features of the previously introduced 'thin-scalloped biotype'. A clear thick gingiva was found in about two thirds of the sample in mainly male subjects. About half of them showed quadratic teeth, a broad zone of keratinized tissue and a flat gingival margin corresponding to the features of the previously introduced 'thick-flat biotype'. The other half could not be classified as such. These subjects

showed a clear thick gingiva with slender teeth, a narrow zone of keratinized tissue and a high gingival scallop.

Another important issue relates to the implant characteristics, which was included in chapter 5. Recently, implant companies have introduced two-piece implants with micro-textured collars in the interest of hard tissue preservation and/or soft tissue integration. However, these arguments may be premature. At present, it is unclear whether micro-roughened implant necks reduce crestal bone loss. A possible effect may be overruled by the establishment of a biologic width or by other factors influencing crestal bone remodeling. In addition, the orientation and attachment of the collagen fibbers in the peri-implant mucosa are little different as the surface roughness varies at the level of the implant neck. By consequence, micro-roughened implant collars do not provide an obvious advantage. What is more, the long-term impact of these modified collars on the initiation and progression of peri-implant pathology is currently unknown. In conclusion, the clinician should be reserved when using these modified implants. Consequently only screw-type tapered implants with a micro-roughened body and machined collar were adopted in our studies.

In our one-year prospective clinical study (chapter 6) all patients underwent the same strategy; that is mucoperiosteal flap elevation, immediate implant placement, insertion of a grafting material between the implant and the socket wall and the connection of a screw-retained provisional restoration. The objective of the study was to assess implant survival, hard and soft tissue response and esthetic outcome. Short-term results on implant survival and hard tissue alterations were at least comparable to the outcome of the conventional procedure. Papilla loss and midfacial soft tissue shrinkage were limited to approximately 0.5 mm after one year of observation. Based on these preliminary promising results the proposed treatment protocol was considered a viable solution for well-selected cases. However, as hard and soft tissue alterations are a continuous event further long-term evaluation is required.

In chapter 7, the influence of the restorative procedure on the esthetic treatment outcome of the immediate single tooth implant in the anterior maxilla was assessed. Whether the implant was immediately restored or not had no influence on the osseointegration or bone remodeling process. However, it had a significant impact on the soft tissues surrounding the implant. If the implant was not immediately provisionalized, papillae were lost and took up to one year to attain the same height as when the implant was immediately restored. Even more important for esthetics was the additional loss of midfacial soft tissue by 0.75 mm on average, which showed a permanent character during the study period. By consequence, if the condition of the selected case permits it, immediate provisionalization should be advised to minimize midfacial soft tissue shrinkage.

Chapter 8 is attributed to the suprastucture, and gives a detailed description of four restorative key elements essential to obtain an optimal esthetic outcome. A first one is to instantly provisionalize the immediate single-tooth implant in light of optimal soft tissue preservation. Second, the provisional restoration should meet a number of morphological prerequisites. A third restorative factor includes the accurate replication of the soft tissue architecture for the permanent restoration in order to avoid subsequent soft tissue changes.

And finally a fourth factor decisive for success relates to the choice of the abutment material.

This thesis showed that the immediate replacement of a failing tooth with an implant and screw-retained restoration is a viable treatment concept. It is an appealing strategy for as well the patient as the clinician. However, careful patient selection, treatment planning and experienced clinicians seem of critical importance to obtain optimal esthetics. Future research should consider long-term prospective and controlled clinical studies in order to document the overall outcome of this treatment strategy.

SAMENVATTING

Het verlies van een tand in de esthetische regio is voor de meeste patiënten een traumatische gebeurtenis. Vandaag beschikken we over verschillende behandelingsmogelijkheden ter vervanging van een gebitselement, zoals een adhesiefbrug of een conventioneel brugwerk. Sinds de komst van implantaten in de jaren tachtig en de publicatie van talrijke veelbelovende studies, is de populariteit van de implantaat-gedragen kroon gestegen. De oorspronkelijke procedure behelzde een eerste chirurgische ingreep waarbij het implantaat in het kaakbot geplaatst werd, gevolgd door een submucosale genezingsperiode van 3 tot 6 maanden. Daarna was een tweede chirurgische ingreep nodig om het implantaat vrij te leggen. Deze langdurige behandeling is vaak een belangrijke reden om af te zien van een behandeling met een implantaat-gedragen restauratie. Een snellere opeenvolging van de verschillende behandelingsequenties drong zich op. In het licht van dit argument waren verscheidene klinici geneigd om de implantaten kort of onmiddellijk na extractie te plaatsen en deze zo snel mogelijk of onmiddellijk te verbinden met een kroon (hoofdstuk 1).

Hoofdstuk 2 geeft een overzicht van de bestaande literatuur omtrent de onmiddellijke vervanging van een falende tand in de premaxilla. Hieruit blijkt dat de succespercentages van de implantaten en zelfs het beheer van het harde weefsel voorspelbaar lijken. De succespercentages van het beperkt aantal studies waren op zijn minst vergelijkbaar met deze van het oorspronkelijke protocol. Verder was het peri-implantair botverlies niet groter dan 1 mm na 1 jaar opvolging. Echter, in de afgelopen tien jaar zijn de criteria voor succes veranderd en werd het esthetisch eindresultaat belangrijk. Van cruciaal belang hiervoor is een optimaal behoud van de bestaande zachte weefsels. De papil niveaus leken vrij voorspelbaar, daar deze niet rechtstreeks worden beïnvloed door de chirurgische/restauratieve procedure. Echter, het behoud van het midfaciale zachte weefsel niveau leek minder voorspelbaar. Aangezien de momenteel beschikbare informatie over dit onderwerp zeer schaars is, moet de tandarts enige voorzichtigheid aan de dag leggen bij het onmiddellijke vervangen van een verloren tand door een implantaat-gedragen restauratie in de esthetische regio van de bovenkaak. Bij het indiceren zullen op zijn minst een aantal strikte richtlijnen en voorwaarden moeten in acht genomen worden.

Het algemene doel van deze thesis was om deze richtlijnen en voorwaarden op te helderen. Verder werd het esthetisch resultaat van de onmiddellijke implantaat-gedragen enkel tandsvervanging in de premaxilla na 1 jaar beoordeeld. De belangrijkste vragen in dit verband hebben betrekking op de patiëntselectie, implantaatselectie en het behandelingsprotocol (hoofdstuk 3).

Wat betreft een goede patiëntselectie, is de bepaling van het gingivaal biotype van bijzonder belang voor de klinicus, aangezien patiënten met een dunne gingiva een hoger risico voor esthetische complicaties vertonen. Op basis van deze mogelijke risico's werden patiënten met een dun biotype systematisch uitgesloten in onze studies.

Hoofdstuk 4 behandelt de prevalentie van de verschillende gingivale biotypes. Uit een grote groep jong volwassenen konden op basis van eenvoudige diagnostische parameters 3 clusters met specifieke kenmerken worden geïdentificeerd. Een duidelijke dunne gingiva werd waargenomen in ongeveer een derde van de onderzoeksgroep. Het waren voornamelijk vrouwelijke personen met slanke tanden, een smalle zone aan gekeratiniseerde gingiva en uitgesproken papillen. Deze kenmerken komen overeen met deze van het eerder geïntroduceerde 'dun biotype'. Een duidelijke dikke gingiva werd gevonden in ongeveer tweederde van de onderzoeksgroep bij voornamelijk mannelijke personen. Ongeveer de helft van hen vertoonde kwadratische tanden, een brede zone aan gekeratiniseerde gingiva en een vlak verloop van de tandvleesrand. Dergelijke kenmerken zijn vergelijkbaar met deze van het eerder geïntroduceerde 'dik biotype'. De andere helft vertoonde een duidelijk dikke gingiva met slanke tanden, een smalle zone van gekeratiniseerd tandvlees en uitgesproken papillen.

Onlangs introduceerden verschillende bedrijven tweedelige implantaten met een opgeruwde implantaathals, met het oog op een beter behoud van de harde weefsels en/of integratie van de zachte weefsels. Echter, dit argument is wellicht voorbarig. In hoofdstuk 5 werden deze geclaimde voordelen kritisch onderzocht op basis van eerder verschenen studies. Momenteel is het onduidelijk of de micro-gestructureerde implantaathals het botverlies vermindert. Een mogelijk effect kan worden herroepen door het instellen van een adekwate biologische breedte of door andere factoren die peri-implantaire botveranderingen beïnvloeden. Bovendien is de oriëntatie en bevestiging van de collageen vezels in de peri-implantaat mucosa weinig verschillend wanneer de oppervlakteruwheid van de implantaathals varieert. Aldus is het tot op heden niet duidelijk of een opgeruwde implantaathals voordelen biedt. Integendeel, de invloed op lange termijn van deze gewijzigde kragen op de initiatie en progressie van peri-implantaat pathologieën is momenteel onbekend. Kortom, de tandarts zou voorzichtig moeten omgaan bij het gebruik van deze gemodificeerde implantaten. Daarom werden alleen schroefvormige conische implantaten met een micro-gestructureerd oppervlak en een gladde implantaathals aangewend in de uitgevoerde studies.

In de studie beschreven in hoofdstuk 6 ondergingen alle patiënten dezelfde behandelstrategie, namelijk een mucoperiostale flap, onmiddellijke plaatsing van het implantaat na extractie, opvullen van de resterende ruimte tussen implantaat en vestibulaire alveolewand met een traag resorberend bot-substituut en de connectie van een verschroefde tijdelijke restauratie. De volgende parameters werden gedurende deze studie beoordeeld: implantaatsuccespercentage, harde en zachte weefsel respons en het esthetisch eindresultaat. De korte termijn resultaten wat betreft succespercentage en harde weefsel wijzigingen waren ten minste vergelijkbaar met deze van de klassieke procedure. Papilverlies en midfaciale tandvleeskrimp beperkten zich tot ongeveer 0,5 mm na één jaar. Op basis van deze voorlopige veelbelovende resultaten kon besloten worden dat de voorgestelde behandeling een haalbare oplossing is voor goed geselecteerde patiënten. Echter, aangezien de veranderingen van de harde en zachte weefsels een continu gebeuren zijn, is het noodzakelijk deze verder te evalueren op lange termijn.

In de studie, die in hoofdstuk 7 werd uitgevoerd, werd de invloed van de restauratieve procedure op het esthetisch eindresultaat beoordeeld bij implantaten die onmiddellijk na extractie geplaatst werden. Of het implantaat onmiddellijk werd geconnecteerd met een tijdelijke kroon of niet heeft geen invloed op de osseointegratie of de botveranderingen. Echter, dit had wel een grotere invloed op de zachte weefsels rond het implantaat. Wanneer het plaatsen van een implantaat gevolgd werd door een submucosale genezing, gingen de papillen verloren en duurde het tot één jaar alvorens ze opnieuw dezelfde hoogte bereikten als wanneer het implantaat onmiddellijk werd voorzien van een tijdelijke kroon. Nog belangrijker voor de esthetiek was het bijkomende verlies van het midfaciale zachte weefsel (0,75 mm). Dit extra gingiva verlies tengevolge van het niet onmiddellijk plaatsen van een voorlopige kroon had een permanent karakter tijdens de volledige studie periode. Bijgevolg, indien de voorwaarden voor het onmiddellijk belasten van het implantaat vervuld zijn, is het onmiddellijk connecteren van een tijdelijke kroon geadviseerd om deze zachte weefselkrimp te vermijden.

Hoofdstuk 8 is gewijd aan de suprastuctuur, en geeft een gedetailleerde beschrijving van vier restauratieve elementen die van essentieel belang zijn voor het verkrijgen van een optimaal esthetisch eindresultaat. In de eerste plaats wordt geadviseerd om een immediaat implantaat onmiddellijk te voorzien van een voorlopige kroon om op die manier de zachte weefsels optimaal te behouden. Ten tweede, de voorlopige restauratie moet aan een aantal morfologische voorwaarden voldoen. Een derde factor bestaat erin de zorgvuldig gevormde zachte weefsel architectuur nauwkeurig te repliceren naar de definitieve restauratie om nadien zachte weefselveranderingen te voorkomen. En tot slot een vierde factor doorslaggevend voor esthetisch succes heeft betrekking op de keuze van het abutment materiaal.

Dit proefschrift heeft aangetoond dat het onmiddellijk vervangen van een falende tand een mogelijke behandeling is. Het is een aantrekkelijke strategie voor zowel de patiënt als de tandarts. Echter, een zorgvuldige patiëntselectie, behandelplanning en ervaren clinici zijn van cruciaal belang om een optimaal esthetisch eindresultaat te verkrijgen. Toekomstig onderzoek dringt zich op om de lange-termijn resultaten van deze behandeling te documenteren.

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13. …

POSTERS

De Rouck Tim, Collys Kristiaan, Wyn Iris, Cosyn Jan

1° prijs VVT Congres 2005: Innovatieve toepassingen bij de frameprothese

SPREKER

1. Computer Guided Implantology: from dream to realization. ZOL 25 & 26 april 2003
2. ipaVUB cursus: Ontwerpen van een frameprothese.
   Prof. Dr. K. Collys, T. De Rouck, Uitneembare Prothetiek.
3. ipaVUB cursus: Overkappingsprothese op implantaten.
   Dr. J. Cosyn en I. Wyn, Parodontologie; T. De Rouck, Uitneembare Prothetiek.
4. ipaVUB cursus: Leerzame mislukkingen. Interdisciplinaire samenwerking.
   Prof. Dr. P. Bottenberg en G. Slaus, Conserverende tandheelkunde; Prof. Dr. K. Collys en T. De Rouck, Uitneembare prothetiek; M. Leconte, Vaste prothetiek; Prof. Dr. Vande Vannet, Orthodontie; Prof. Dr. M. Moradi, Parodontologie.
5. ipaVUB cursus: Solitaire fronttandvervanging door middel van een implantaat.
   Dr. J. Cosyn, Parodontologie; T. De Rouck, Uitneembare Prothetiek.
6. ipaVUB cursus: Klassiek en implantaatgedragen kroon- en brugwerk van het bovenfront.
   Dr. J. Cosyn, Parodontologie; T. De Rouck, Uitneembare Prothetiek.
7. Studieclub cursussen